PDGO. 75. II. (Combined)
750-1978 (DSK. II)

English Translation
of
BHARATIYA JYOTISH SASTRA
(History of Indian Astronomy)

by

Sankar Balakrishna Dikshit

[Translated by Prof. R. V. Vaidya, M. A. B. T.]

PART II

History of Astronomy during the Siddhantic and Modern periods

PRINTED BY THE GENERAL MANAGER, GOVT. OF INDIA PRESS (PUB. UNIT), SANTRAGACHI, HOWRAH-4 AND PUBLISHED BY THE CONTROLLER OF PUBLICATIONS, CIVIL LINES, DELHI, 1981.

Sale Price : Inland Rs. 89.00. Foreign £ 11.55 or 35 $ 64 Cents.

PREFACE

A treatise in Marathi "Bharatiya Jyotish Sastracha Prachin Ani Arvachin Itihas" by Sankar Balakrishna Dikshit, first published in the year 1896, is perhaps the only book on the history of the Indian Astronomy from ancient to modern times. Publication of an English translation of this monumental work was undertaken by the Meteorological Department of India in accordance with a recommendation by the late Professor M. N. Saha, D.Sc., F.R.S., Chairman of the Calendar Reform Committee. The first part of the English translation of this treatise, namely, "Bharatiya Jyotish Sastra, Part I" containing a history of Indian Astronomy in the Vedic and Vedanga period from ancient times upto 1000 B.C. was published by this department in 1968. The present volume contains an English translation of the remaining parts of the original treatise on the Siddhantic and the Modern periods.

The translation of this treatise from Marathi to English was made by the late Professor R. V. Vaidya, a Marathi scholar and former Superintendent of Shree Jiwaji Observatory of Ujjain. He was also a member of the Calendar Reform Committee. This translation was also touched up by the late Professor P. C. Sen Gupta, a renowned Professor of Hindu Astronomy of the Calcutta University. The final editing of this volume has been made under the supervision of Shri A. Bandyopadhyay, Director, Positional Astronomy Centre of the Department at Calcutta. We expect this English translation of Dikshit's excellent treatise will help scholars, both in India and abroad, to appreciate the remarkable achievement of Indian Astronomy during the ancient and medieval periods.

India Meteorological Department,
Mausam Bhavan, Lodi Road,
New Delhi-110003.
16 September, 1981
(25 Bhadra, 1903 S.E.)

P. K. DAS,
Director General of Meteorology.

BHARATIYA JYOTISH SASTRA

PART II

History of Astronomy during the Siddhantic and Modern Periods

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

TRANSLITERATION

The scheme of transliteration of Sanskrit alphabets into Roman script adopted in this publication is the same as generally followed. The corresponding scripts are given below :

अ	आ	इ	ई	उ	ऊ
a	ā	i	ī	u	ū
ऋ	लृ	ए	ऐ	ओ	औ
ṛ	ḷ	e	ai	o	ou
क्	ख्	ग्	घ्	ङ	
k	kh	g	gh	ṅ	
च्	छ्	ज्	झ्	ञ	
c	ch	j	jh	ñ	
ट्	ठ	ड्	ढ्	ण्	
ṭ	ṭh	ḍ	ḍh	ṇ	
त्	थ्	द्	ध्	न	
t	th	d	dh	n	
प्	फ्	ब्	भ्	म्	
p	ph	b	bh	m	
य्	र	ल्	व्	श्	
y	r	l	v	ś	
ष्	स्	ह	ं	:	
ṣ	s	h	ṃ	ḥ	

PART TWO

HISTORY OF ASTRONOMY
IN
JYOTIṢA SIDDHĀNTA PERIOD

1 GAṆITA SKANDHA (MATHEMATICAL BRANCH)

A : Madhyamādhikāra (Adhikāra on Mean Places)

CHAPTER I

History of astronomical Works and Computation of mean places of Planets etc.

FOREWARD

As mentioned in the INTRODUCTION,* the author proposes to discuss the History of the science of Astronomy from about 500 years before Śaka era to this day, and in the beginning, this first chapter of the *Madhyamādhikāra* (i.e. a section on mean places) under the GAṆITA SKANDHA (i.e. a Branch of Mathematics) will deal with the history of astronomical works and the question of computing the mean motions and places of planets.

The knowledge of astronomy as developed during the Vedic and Vedāṅga Jyotiṣa periods and described in Part I, was considerable as compared with the pace of general progress during the period ; but it would appear very meagre, when compared with the ability (developed in a later period) to predict the true positions of planets. It appears that some works might have been compiled during the interval between these periods. There may be some Saṃhitā works of that type ; but they are either not available now or have not been seen by him. The period of Siddhāntic astronomy can somehow be linked with the ancient period. This point will be discussed later on ; but we have no information as to how the knowledge of astronomy reached the highest stage of calculating the true motions and places of planets, how observations used to be taken and how the motions of planets were finally fixed after comparing the different observations. The oldest of astronomical (Siddhānta) works reveal a sudden rise in the standard of astronomical knowledge. Those who raised the standard of such knowledge through their works were naturally regarded as superhuman, and thus arose the popular belief that the available ancient works on mathematical astronomy are regarded as 'apauruṣeya' (i.e. not compiled by any mortal man), and it is clear that this belief has been formed later.

Because these works were regarded as superhuman, they naturally did not include the description of subjects like observations. There seems to be another very strong reason for this omission. Looking to the conditions of those days when as a rule 'shorter the works, the easier they were to commit to memory', such works dealt with only the rules of calculating the motions and places of planets, and they appear to have avoided length by omitting the underlying theory.

---

*Pulished in part I of the book

The author proposes to deal with all works on astronomy in chronological order in this chapter on mean places. Their points of differences, if any, with matters pertaining to other Adhikāras from different works, as also some special points worth mentioning, have been treated in subsequent chapters; otherwise, all information about the works has been given in this very chapter on mean places. Some works are considered divine while some authors have more than one book to their credit; hence, the following account is arranged under the names of authors, and at places, under the titles of their works.

The oldest known works on astronomy are the five Siddhāntas—the Sūrya Siddhānta and others. These are regarded as divine. They are again of two kinds. The Pañcasiddhāntikā of Varāhamihira mentions the Saura and other four Siddhāntas; but at present they are not available. The Pañcasiddhāntikā simply provides clues to their elements. The author calls them the 'ancient Siddhānta Pañcaka' or 'group of five ancient Siddhāntas'. There are five other Siddhāntas likewise entitled the Saura, which are at present available. He calls them 'the modern group of five Siddhāntas'. These will presently be dealt with. First he takes up for consideration the group of five ancient Siddhāntas. These belong to the 5th century before Śaka era. Some of them may belong to an even earlier period.

The group of five ancient Siddhāntas

The following are the Siddhāntas mentioned by Varāhamihira :—

पौलिशरोमकवसिष्ठसौरपैतामहास्तु पंचसिद्धांता: ॥

Pauliśa, Romaka, Vasiṣṭha, Saura and Paitāmaha are the five Siddhāntas.

The elements described by the Pañcasiddhāntikā show that the Siddhāntas were different from the five modern Siddhāntas. Not only are these not available at present, but even the original work, entitled Pañcasiddhāntikā is not available and so, not much is known to any one on this side. Two copies of the work brought from Kashmir by Dr. Buhler are preserved in the Government collection of Manuscripts in the Deccan College (*See* Reg. No. 37 of 1874-75 and No. 338 of 1879-80); but these are very incorrect and incomplete and one is unable to find, at places, where one āryā (couplet) ends and the next one begins. The author has written out for himself a copy from the two versions, and calculations made therefrom have shown that the Sūrya and other Siddhāntas described in it, are different from the modern ones, in that they differ in the length of the year and the motions of planets. The astronomical works compiled during the last 800 years do not show that any ore knew that there existed before a Sūrya-Siddhānta different from the modern one. He came to know of their existence in 1887 and no doubt reed be entertained about it, since this can be proved by calculations and by other evidence. The booklet of the Pañcasiddhāntikā is very incorrect and the major portion of it is unintelligible for want of a commentary; however mary important points have been understood.. *The author would, therefore, describe briefly the five Siddhāntas in the order of the dates of their compilation as found by him.

*Dr. Thibaut published in 1889 A.D. the Pañcasiddhāntikā based on the Deccan College versions. It also gives a new commentary by Sudhākara Dvivedī. The author could not find time to read the whole of it uptil now. However all the important information which he could glean from the Pañcasiddhāntikā has already been given above.

Varāhamihira, in the very first chapter of Pañcasiddhāntikā, observes as follows :—

पौलिशाति* विस्फुटोसौ तस्यासन्नस्तु रोमकः प्रोक्तः ॥
स्पष्टतरः सावित्रः परिशेषौ दूरविभ्रष्टौ ॥ ४ ॥

"The Siddhānta made by Pauliśa is accurate ; near to it stands the Siddhānta by Romaka ; more accurate still is the Sāvitra (Saura). The two remaining ones are far from truth."

This shows that the Pauliśa Siddhānta was very clear at the time of the compilation of Pañcasiddhāntikā, which means that its calculations very much agreed with the actual observed positions. The Romaka was nearer to it in correctness. The Sūrya-Siddhānta was better than both and the remaining two (Vasiṣtha and Pitāmaha) were far removed from correctness meaning that their calculations did not agree with the observed results. The Pitāmaha Siddhānta and Vasiṣtha Siddhānta must have been the oldest of the five, and of the these two, in the author's opinion, Pitāmaha Siddhānta must have been the more ancient. The reasons for this will be given later on. Let us now consider the Pitāmaha Siddhānta.

PITĀMAHA SIDDHĀNTA

The Subject matter

The basic principles underlying the Pitāmaha Siddhānta have been given in the 12th chapter of the Pañcasiddhāntikā. That chapter contains only five *ārysā* (couplets). Nowhere else in the Pañcasiddhāntikā is found anything about this Siddhānta. The first two of the five couplets run thus :—

रविशशिनोः पंच युगं वर्षाणि पितामहं पदिरटानि ॥ अधिमासस्त्रिंशद्भिर्मासैरवमस्त्रिषष्टयाह्नां ॥
द्व्यनं शकेद्रकालं पंचभिरुद्धन्य शेषवर्षाणा ॥ द्युगण माघसिताद्यं कुर्यादद्युगणस्तदन्युदयात् २ ।

"According to the teaching of Pitāmaha, five years constitute a yuga of the sun and the moon. The adhimāsas occur after thirty months and an omitted lunar day (avam) once in sixty three days. Lessen the time of the Śaka King by two and divide the remainder*by five ; with the remaining years find the ahargaṇa, counting from the first day of the light half of Māgha. The Ahargaṇa thus found begins with sunrise".

The fifth couplet describes the method of calculating the length of the day :—

द्विघ्नं शशिरस (६१) भक्तं † द्वादशहीनं दिवसमानं ॥

"Multiplying (the number of days elapsed after winter solstice or the number of days to go before the end of the ayana beginning with summer-solstice) by 2 divide by 61. Add 12 (muhūrtas) to the quotient, and the result will be the length of the day".

---

*The author copied out the couplets from the Pañcasiddhāntikā, exactly as they are written in his book. Dr. Thibaut has introduced new readings in the next and he has accepted at places only such of them which were considered suitable.

†The word 'hinam' in this couplet is incorrect ; the proper word must be 'yuktam'. The first half of the couplet is incorrect and has not, therefore, been given here, but it means nothing more than that has been given above within brackets.

not similar to the Brahmagupta Siddhānta. This shows that the Brahma Siddhānta to which Brahmagupta has referred as containing mathematics explained by Brahmā, must have been different from the Brahma Siddhāntas of Śākalya Saṃhitā and Viṣṇudharmottarapurāṇa and it must be the same as the Pitāmaha Siddhānta of the Pañcasiddhāntikā. The Vedāṅga Jyotiṣa does not deal with the calculation of planets other than the sun and the moon ; and the Pitāmaha Siddhānta of the Pañcasiddhāntikā also describes the calculations of the sun and the moon only. Varāhamihira has given the calculations of all planets in the case of only the Sūrya-Siddhānta out of the five Siddhāntas and mentions nothing about the planetary calculations contained in the Pitāmaha Siddhānta. It must have, however, contained the calculations of planets as remarked by Brahmagupta, and Varāhamihira appears to have omitted it, on finding that it did not agree with the actual observed places on account of lapse of time. A Pitāmaha Siddhānta, different from the one described in the Pañcasiddhāntikā, does not appear to have ever existed before Brahmagupta. The words "planetary calculations given by Brahmā" occurring in Brahmagupta's work must certainly be referring to the Pitāmaha Siddhānta of the Pañcasiddhāntikā, and the remark, "a long time has elapsed" also refers to the same Pitāmaha Siddhānta. It follows, therefore, that it must have been compiled long before the Śaka era.

Āryabhaṭa and Brahmagupta appear to have expressed veneration for the Pitāmaha Siddhānta only as a formality, because their siddhāntas and the Pitāmaha Siddhānta of the Pañcasiddhāntikā have nothing in common. It has already been pointed out in the course of the study of the Vedāṅga Jyotiṣa that Brahmagupta has openly found fault with the five-year Yuga system. Still, these arguments in no way affect the inference that there existed a Siddhānta knowr as the Pitāmaha Siddhānta before these two astronomers lived.

The System

The Pañcasiddhāntikā gives in the beginning two couplets relating to the Pitāmaha Siddhānta, the first of which contains the expression,

अधिमासस्त्रिंशद्भिर्मासैः

meaning, "an intercalary month to be reckoned after 30 months". It has been shown in the study of Vedāṅga Jyotiṣa that the adoption of an intercalary month after 30 months causes a grave error ; but this very couplet has been cited by Bhaṭotpala in his commentary on Vṛhatsaṃhitā in connection with the verse "*ekaikamabdeṣu*" in Chapter 8. The reading there is "*adhimāso dwyagnisamairmāsaiḥ*" which means that ar intercalary month is to be reckoned after 32 months. Again the same couplet is found in the commentary (Chapter I) by Mahādeo on Śrīpati's Ratnamālā and it also gives "adhimāso dwyagnisamaiḥ" as the reading. It is strange that there is room for confusion due to doubtful readings at such an important place.

If it be assumed that Utpala and Mahādeo changed the original reading *viz.* "triṃśatbhirmāsaiḥ", why should they have substituted "dwyagnisamaiḥ" as the reading ? The intercalary month occurs after more than 32½ months, and hence, they could have as well substituted some words meaning 32½ or 33. It appears, therefore, that "dwyagnisamaiḥ" must have been the original reading. According to the Vedāṅga Jyotiṣa one day (tithi) is suppressed after 62 days, while the above couplet mentions the suppression of one dav

as occuring after 63 days (tithis). This shows that the Vedāṅga Jyotiṣa and the Pitāmaha Siddhānta are not similar to each other completely, and this also lends an additional support to the view that "dwyagnisamaiḥ" must have been the original reading.

The number of intercalary months in 8 years comes to be 3 at the rate of one intercalary month in 32 months. This gives 99 as the number of lunar months in 8 years and 2970 as the number of tithis (lunar days) ; and $47\frac{1}{7}$ lunar days will be suppressed during this number of tithis at the rate of one suppressed tithi per 63 lunar days. Hence, 8 years will be equal to $2922\frac{6}{7}$ sāvana days or one year will be equivalent to 365 days and $21\frac{3}{7}$ ghaṭis. This measure of a year is more accurate than that found in the Vedāṅga Jyotiṣa.

The Pitāmaha Siddhānta existed before Āryabhaṭa, Varāhamihira, and Brahmagupta. As it had fallen into disuse in their times it is evident that it must have beer compiled long before them. It is similar to the Vedāṅga Jyotiṣa but differs from it much. Brahmagupta's statement shows that it (the Pitāmaha Siddhānta) contained the calculations of Mars and other planets, which is not given in the Vedāṅga Jyotiṣa. It proves that a more accurate work known as the Pitāmaha Siddhānta was compiled sometime after the Vedāṅga Jyotiṣa and this is an important fact. If it were known how the places of Mars and other planets used to be calculated according to the Pitāmaha Siddhānta, it would have been found very useful in tracing the growth of Indian astornomy ; but we have almost no hopes of obtaining the Pitāmaha Siddhānta now in its original form.

VASIṢṬHA SIDDHĀNTA

The Date

The Pañcasiddhāntikā contains 13 āryās (couplets) relating to Vasiṣṭha Siddhānta. The system described by it is somewhat different from that met with in other siddhāntic works. This fact and also the statement of Varāhamihira that "Vasiṣṭha is very inaccurate" leads one to infer that it must have been more ancient than the remaining three siddhārtas excepting the Pitāmaha Siddhānta.

The System

The thirteen couplets show that they mention nothing about planets other than the sun and the moon. The method of calculating tithis and nakṣatras is not similar to that of the present day. It mentions the rāśi (sign), aṃśa (degree) and Kalā (minutes) as the units and the subject of 'shadow' has been considered at length. Something has been told about the length of the day and the word 'lagna' (ascendant) has been used in a somewhat present day sense. The Vasiṣṭha Siddhānta, available at present, is in no way similar to the one existing before Varāhamihira's time and did not exist in his time. This question will be discussed again later on.

Different versions of Vasiṣṭha and Romaka Siddhāntas

Two versions of the Vasiṣṭha and Romaka Siddhāntas were known at the time of Brahmagupta (Śaka 550). The case of Romaka Siddhānta will automatically be considered along with the evidence on the basis of which it is to be proved that there were two kinds of Vasiṣṭha Siddhānta. Let both of them, therefore, be considered here together.

Brahmagupta says at one place in his Siddhānta,

पौलिशरोमकवासिष्ठसौरपैतामहेषु यत्प्रोक्तं ।। तन्नक्षत्रानयनं नार्यभटोक्तं तदुक्तिरतः ।। ४६ ।

अध्याय १४

"I describe the 'nakṣatrānayana' i.e. the method of calculating nakṣatras, which has been given by other Siddhāntas *viz.* Pauliśa, Romaka, Vāsiṣṭha, Saura and Paitāmaha but not given by Āryabhaṭa".

He observes at another place,

अयमेव कृतः सूर्येंदुपुलिशरोमकवसिष्ठयवनाद्यैः ।।

अध्या. २४ आर्या ३.

"This very (beginning of a yuga) has been adopted by Sūrya, Indu, Puliśa Romaka, Vasiṣṭha and Yavana".

Brahmagupta has cited as authority of the Sūrya and other Siddhāntas because these were in his favour. The Brahmagupta Siddhānta as a whole, appears to have launched a vigorous attack against Āryabhaṭa and others. He is, as it were, showering volleys of vituperation. Even then he has not made any direct attack against the group of first (Sūryādi) five Siddhāntal except the Romaka, and he has explicitly found fault with the Pattern, ony once, as may be seen from the following couplet :—

युगमन्वंतरकल्पाः कालपरिच्छेदकाः स्मृतावुक्ताः ।।
यस्मान्न रोमके ते स्मृतिबाह्यो रोमकस्तस्मात् ।। १३ ।।

अध्याय १.

"The smṛti works mention yuga, manvantara and kalpa as the broad units of time. The Romaka has violated the Smṛtis since it does not mention them".

Brahmagupta, at another place, observes,

लाटात्सूर्यशशांकौ मध्याविंदुच्चचंद्रपातौ च ।।
कुजबुधशीघ्रबृहस्पतिसितशीघ्रशनैश्चरान् मध्मान् ।। ४८ ।।
युगयातवर्षभगणान् वासिष्टात् विजयनंदिकृतपादान् ।।
मंदोच्चपरिधिपातस्पष्टीकरणाद्यमार्यभटात् ।। ४६ ।।]
श्रीषेणेन गृहीत्वा रत्नोच्चयरोमकः कृतः कंथा ।।
एतान्येव गृहीत्वा वासिष्टो विष्णुचंद्रेण ।। ५० ।।

अध्याय ११.

The gist

"Śrīṣeṇa has compiled a 'kanthā' (i.e. a patch work) entitled as Romaka, by borrowing elements from different Siddhāntas, e.g. (i) mean sun and moon,

moon's apogee, moon's node, Mars, Mercury, Jupiter, Venus, and Saturn from Lāṭa's work (ii) elapsed years of yugas and bhagaṇa (sidereal revolutions) from Vasiṣṭha (iii) the pāda (quadrants) from Vijayanandi's works and (iv) mandocca, aphelia, paridhi (epicycle), nodes of planetary orbits and calculations of true places from Āryabhaṭīya. Viṣṇucandra has similarly, compiled the Vasiṣṭha Siddhānta by borrowing the same elements".

It has been said above that Viṣṇucandra has borrowed the same elements from other works in compiling the Vasiṣṭha Siddhānta as Śrīṣeṇa had borrowed in compiling the Romaka Siddhānta, and it has also been observed that Śrīṣeṇa took the bhagaṇas and the elapsed years of yugas from the Vasiṣṭha This shows that Viṣṇucandra also adopted the same elements from the Vasiṣṭha Siddhānta and other information from other Siddhāntas and compiled another Vasiṣṭha Siddhānta. It, therefore, shows that there existed two kinds of Vasiṣṭha Siddhāntas and that this was known to Brahmagupta. One of them was the original Vasiṣṭha Siddhānta and the other was Viṣṇucandra's Vasiṣṭha Siddhānta, compiled by borrowing some elements from the first.

It has already been remarked before that Brahmagupta has abused Romaka Siddhānta as 'a violator of Smṛti', because it does not give the time units of yuga, manvantara and kalpa ; but it has also been shown above that Brahmagupta himself says that Śrīṣeṇa picked up the figures for 'elapsed years of yuga', from the Vasiṣṭha Siddhānta while compiling the Romoka Siddhānta. Similarly, he again observes,

तद्युगबधो महायुगमुक्तं श्रीषेणविष्णुचंद्राद्यैः ॥

अ० ११ आर्या ५५.

मेषादितः प्रवृत्ता नार्यभटस्य स्फुटा युगस्यादौ ॥ श्रीषेणस्य कुजाद्याः

अ० २ आ० ४६.

"That Śrīṣeṇa, Viṣṇucandra and other authors have mentioned 'Mahāyugas as a multiplicity of yugas"...

"Śrīṣeṇa has not given true positions of Mars and others from the commencement of a yuga, as is done by Āryabhaṭa, but from the beginning of Meṣa".

Thus, according to the statement of Brahmagupta himself, the Romaka Siddhānta by Śrīṣeṇa did contain the yuga system and from this (it can be inferred that) there were two siddhāntas named Romaka, at the time of Brahmagupta— the one known as the original Romaka Siddhānta and the other, that 'compiled by Śrīṣeṇa'.

Most of the names of astronomers who lived before Brahmagupta and who have been mentioned in his Siddhānta, are found in the Pañcasiddhāntikā. However, the names of Śrīṣeṇa and Viṣṇucandra are not found in the Pañcasiddhāntikā which mentions only one Siddhānta each, named as Vaśiṣṭha and Romaka. This goes to show that Śrīṣeṇa's Romaka Siddhānta and Viṣṇucandra's Vasiṣṭha did not exist before Śaka 427, and that only the original Romaka Siddhānta and the original Vasiṣṭha Siddhānta existed then and these are given in the Pañcasiddhāntikā only in summary form. According to Brahmagupta, Śrīṣeṇa and Viṣṇucandra borrowed the method of finding true places from Āryabhaṭa. This also shows that they compiled their res-

pective Siddhāntas after Śaka 421 while the Pañcasiddhāntikā leads to the conclusion that they were compiled after the Śaka 427.

ROMAKA SIDDHĀNTA

It has been pointed out above that out of the two Romaka Siddhāntas described, only the original Romaka Siddhānta existed at the time of the Pañcasiddhāntikā. Let us now consider this Romaka Siddhānta.

A large portion of the Pañcasiddhāntikā has been devoted to Romaka Siddhānta. Three couplets of the first chapter beginning from the 8th describe the method of finding the 'ahargaṇa'. The fifteenth couplet mentions the intercalary months and the suppressed tithi. All the 18 'āryās' of the 8th chapter are devoted to Romaka Siddhānta. They describe the calculations of the sun and moon, their true places and the method of calculating solar and lunar eclipses.

The very first couplet giving the method of calculating the 'ahargaṇa' according to the Romaka Siddhānta runs thus :—

सप्ताश्विवेद (४२७) संख्यं शककालमपास्य चैत्रशुक्लादौ ।।
अर्धास्तमिते भानौ यवनपुरे भौमदिवसाद्यः ।। ८ ।।
अध्याय १.

"Deduct the Śaka year 427 from the number of that year for which the ahargaṇa is wanted at the beginning of the light half of Caitra, when the sun was halfset in Yavanapura, at the beginning of Tuesday".

This shows that the first lunar day of Caitra was a Tuesday.

A Karaṇa work is required to give the positions of planets as at the beginning or epoch of that work, for finding the planetary positions. These positions are termed 'kṣepaka'. The 'kṣepakas' as mentioned by the Pañcasiddhāntikā prove to be true for the mean Meṣādi (Sun's entry into Aries), falling on the 14th Lunar day of the dark half of 'amānta' Caitra of Śaka 427 ; i.e. on Sunday, the 20th of March, 505 A.D. There is no doubt that some of them are true for the moon and others for the midnight of that date. This point will be more clearly explained in the study of the Sūrya-Siddhānta later on. The next Śukla 'pratipadā' (i.e. the first lunar day) after the 14th day of the dark half of Caitra, i.e. the first day of the light half of Vaiśākha, is seen to fall on Tuesday. Evidently this very 'pratipadā' was called the 'Caitra-śukla-pratipadā', by Varāhamihira (otherwise, by no other method the Caitra-śukla-pratipadā of Śaka 427, can be shown to fall on Tuesday), and it was no doubt correct that the 'ahargaṇa' is required to be calculated from that day. Varāhamihira appears to have adopted this epoch, because it is convenient to calculate positions from those on the 1st day of the light half. It is a well known fact of mathematical astronomy that the 'ahargaṇa' calculated with the help of any 'Karaṇa work' proves to be correct within a day, and it has to be verified with the help of the day of the week. It may now be questioned as to why the Vaiśākha śukla-pratipadā could have been called the Caitra-śukla-pratipadā by Varāha. I have absolutely no doubt that the śukla-pratipadā following the day for which the Kṣepakas are given is the first day of the Vaiśākha-śukla-halfmonth of Śaka 427 according to the 'amānta' system. The Caitra is

defined as that ending lunar month which ends while the sun is in Meṣa (Aries). As the sun is found to be in Meṣa at the end of that amāvāsyā which fell on the day, next to the day for which the elements have been given irrespective of whether a mean or a true Meṣa was reckoned ; and hence, according to the above definition the amānta lunar month which ended with the amāvāsyā must be termed as Caitra, and Vaiśākha commenced on Tuesday i.e. the next day. But a lunar month belonging to the pūrṇimānta system ends on the full moon day, and hence, the full moon day belonging to that light half which commenced just after the 'kṣepaka' day will coincide with the end of the lunar month. The calculations made on the basis of 'kṣepakas' given by Pañcasiddhāntikā show that the sun still occupied the Meṣa sign, and hence that lunar month naturally received Caitra as its name. The author does not find any other convincing theory to explain how that month could be termed Caitra. The pūrṇimānta system has remained in vogue in Northern India from a very ancient time. Even though the 'pūrṇimānta' system is still in vogue there, the lunar months are not named according to the system described above ; but it appears that the system must have been in use in its pure form at the time of Varāhamihira.

The first couplet of the 8th Chapter gives tne method of finding the sun's place according to the Romaka Siddhānta :—

> सेमकसूर्यो द्युगणात् खतिथि (१५०) घ्नात् पंचकर्तु (६५) परिहीनात् ॥
> सप्ताष्टकसप्तकुतेंद्रियो ५४७८७ द्दृतान्मध्यमार्कः सः ॥

"Multiply the ahargaṇa by 150, deduct 65, and divide the remainder by 54787 ; the result is the mean longitude of the sun".

The sun's position is obtained by multiplying the ahargaṇa by 150, subtracting 65 from the product and by dividing the remainder by 54787. The number 65 is to be subtracted from this because of the Kṣepaka. The figure denoting the sun's longitude is obtained in terms of bhagaṇas etc. (the bhagaṇa means a complete sidereal revolution of a planet through the Zodiac.) There is no doubt about this, although it is not explicit in the couplet. The sun makes 150 complete revolutions in 54787 days and hence, one revolution requires exactly 365 days 14 ghaṭis 48 palas. This is, therefore, the measure of a year according to Romaka. The modern Sūrya-Siddhānta gives 365d 15g 31p 31·4v. as the measure. Brahmagupta has blamed Romaka for not giving measures of yuga and other units, as is done by other Siddhāntas and the following discussion will show that it is true. In order to facilitate the comparison of Romaka with other Siddhāntas, below the figures are given indicating the number of revolutions and other measures relating to the moon in one Mahāyuga i.e., in 4320000 years, which are derived from the elements given by Romaka. The couplets from the Pañcasiddhāntikā on the basis of which these have been calculated are as follows :—

> रोमकयुगकमर्कदोर्वर्षाण्याकाशपंचवसुपक्षः (२८५०)
> खेंद्रियदिशो (१०५०) विमासाः खरकृतविषयाष्टयः (१६५४७) प्रलयाः ॥ १५ ॥
> अध्याय १.

"Romaka's yuga consisted of 2850 years. During this period, the number

of intercalary months is 1050 and that of pralaya's or suppressed tithis is 16547".

शून्यैकैका (११०) म्यस्तान्नवशून्यरसा (६०९) न्वनाद्दिनसमूहात् ।।
रूपत्रिखगुण (३०३१) भक्तात्केंद्रं शशिनोस्तगमवंत्याम ।। ५ ।।
ग्यष्टक (२४) गुणिते दद्याद्रसर्तुयमषदकपंचकान् (५६२६६) राहो: ।।
भवरूपाग्न्यष्टि (१६३१११) हृते...।। ८ ।।

अध्याय ८.

"(5) Multiply the ahargaṇa by 110, add 609, and divide by 3031 ; the quotient gives the position of the moon's *kendra at Sunset at Avantī.*

(8) Multiply the ahargaṇa by 24, add 56266 and divide by 163111 ; the result is the successive position (in revolutions, signs, etc.) of Rāhu (i.e. the moon's ascending node), reckoning backwards from the end of Pisces (i.e. the first point of Aries). (24 revolutions of Rāhu are supposed to take place in 163111 sāvanadays)".

The following figures denoting several astronomical measures are derived from these couplets and from the above couplet describing the calculation of the sun's position and that describing the calculation of ahargaṇa.

Number giving	*During one Mahāyuga 4320000 years*	*During a yuga of 2850 years*
Revolutions of stars	1582185600	1043803
Revolutions of the Sun	4320000	2850
Sāvana days	1577865600	1040953
Revolutions of the Moon	$57751578\frac{18}{19}$	38100
Revolutions of the Moon's apogee	$488258\frac{13708}{57589}$	$322\frac{228}{3031}$
Revolutions of Moon's ascending node	$232165\frac{109085}{163111}$	$153\frac{26889}{163111}$
Solar Months	51840000	34200
Intercalary Months	$1591578\frac{18}{19}$	1050
Lunar Months	$53431578\frac{18}{19}$	35250
Tithis	$1602947368\frac{8}{19}$	1057500
Suppressed Tithis	$25081768\frac{8}{19}$	16547

The numbers showing the revolutions of the moon etc. in one Mahāyuga are not integral numbers. Hence, the sun and the moon, according to Romaka, will not, like other Siddhāntas, come together in the beginning of the Kaliyuga

or a Mahāyuga. Similarly, the number of lunar months is also not an integral number and the Romaka's yuga has been stated to consist of 2850 years. This shows that the Romaka Siddhānta has not followed the system of adopting 4320000 years as the measure for a Mahāyuga.

The couplet describing the method of calculating the moon's place is very incorrect. The author could not calculate the number of the moon's revolutions from it; these have been calculated by a different method.

The kṣepakas at the epoch of the Karaṇa work are found to be as follows :—

Sun	11^s	29°	34′	23″	Moon's Kendra .	2^s	12°	19′	57″
Moon	11	29	18	50	Moon's ascending Node . .	7	25	49	3

The Kṣepakas are true for the moment of sunset at Ujjayinī on Sunday the 14th lunar tithi of Caitra Kṛṣṇa, Śaka 427 (i.e. 20th March 505 A.D.).

Hipparchus, the Greek astronomer, lived about 150 B.C. His figure for the length of the year exactly tallies with that of the Romaka (*viz.* 365d—14gh.—48pal.)

The work of Hipparchus is not available at present, but he had compiled tables for calculating the positions of the sun and the moon only and not for calculating the planets. Well known European astronomers say that the latter were compiled by Ptolemy on the basis of the principles of Hipparchus. They also admit* that the principles of Greek astronomy had already reached India long before Ptolemy's time. The Romaka Siddhānta gives the calculations of only the sun and the moon, and its measure of the year is found in no other Siddhānta. It does not describe 'the universally accepted yuga system' and its name. Romaka appears to be western. All these things go to show that the original Romaka Siddhānta was compiled on the lines of the work of Hipparchus, and it must have been compiled after 150 B.C. and before Ptolemy's time i.e. 150 A.D.

It has already been shown above that the Paitāmaha and Vasiṣṭha Siddhāntas were older than the Romaka. Similarly, it is thought that even the Sūrya Siddhānta and the Puliśa Siddhānta of the Pañcasiddhāntikā are more ancient than the Romaka; for, it is obvious from Brahmagupta's work, that the other four Siddhāntas were regarded with more veneration than the Romaka. He has nowhere blamed any of the four works. After the time of Brahmagupta, the Romaka Siddhānta appears to have gone quite out of use, both in its original form and the form in which it was recast by Śrīṣeṇa. Utpala has nowhere made references to the Romaka on any occasion in his discussion of planetary calculations in his commentary on the Bṛhatsaṃhitā, but he has cited the authority of the four Siddhāntas, *viz.*, those by Puliśa, Sūrya, Āryabhaṭai or by Brahmagupta. The original Romaka Siddhānta seems to have disappeared in its original form at the time of Utpala. The Romaka Siddhānta of the present day gives elements according to the modern Sūrya Siddhānta and not according to any other Siddhānta; and even this Romaka Siddhānta is not much known to any one now-a-days. This shows that the veneration which the other Siddhāntas, out of the group of five, enjoy, is due to their being much more ancient than the Romaka.

*See Grant's History of PhysicalAstronomy [Introuction page (iii)] and page 439); similarly, see English translation of Sūrya Siddhānta, by Burgess, page 330.

One more important proof about the Romaka being more modern than the five Siddhāntas is given below :

Measures of the year according to different works on astronomy.

	Days	Ghaṭi	Pala	Vipala	Prativipala.
Vedāṅga Jyotiṣa	366	..	..	..	..
Pañcasiddhāntikā group :					
1 Pitāmaha Siddhānta	365	21	25	..	..
2 Vasiṣṭha Siddhānta	..	..	..	..	..
3 Puliśa Siddhānta	365	15	30	..	..
4 Sūrya Siddhānta	365	15	31	30	..
5 Romaka Siddhānta	365	14	48	..	..
First Ārya Siddhānta	365	15	31	15	..
Brahmagupta Siddhānta (Modern group)	365	15	30	22	30
Sūrya, Vasiṣṭha, Śākalya, Romaka and Soma Siddhāntas	365	15	31	31	24
Second Ārya Siddhānta	365	15	31	17	6
Rājamṛgāṅka, Karaṇa Kutūhala etc.	365	15	31	17	17¼

Out of these figures indicating the measure of the year, none except that of Romaka are found to be smaller than 365d—15gh—30p, and none, excepting that of the Vedāṅga Jyotiṣa and the Pitāmaha Siddhānta, greater than 365d—15gh—32p. In other words, leaving aside the case of Vedāṅga Jyotiṣa and Pitāmaha Siddhānta, none of the rest, except the Romaka, differ from one another by more than 2 palas. Had Romaka been older than the Puliśa Siddhānta and the Saura Siddhānta of the Pañcasiddhāntikā, all of them would have taken the same year measure, as the Romaka or one with a slight variation, and they could not have strayed very far from the Romaka. This proves beyond doubt that the Puliśa and Saura Siddhāntas were older than the Romaka. It seems beyond doubt that all the Siddhāntas of the Pañcasiddhāntikā belonged to a pre Śaka period.

It is Dr. Thibaut's opinion that the Romaka and the Puliśa Siddhāntas of the Pañcasiddhāntikā are "not more modern than 400 A.D." He means* to say that these two were compiled about the year 400 A.D. and the other Siddhāntas of the Pañcasiddhāntikā group were also compiled about the same year. But the above discussion will show that his view is erroneous.

The figures showing the number of revolutions and other elements, as given in the Romaka Siddhānta, which is available at present, are given later on. A comparison of these figures with the foregoing ones will show that there is absolutely no similarity between them. This shows that the modern Romaka Siddhānta did not exist before Śaka 427.

The question whether the modern Romaka Siddhānta is the same as that compiled by Śriṣeṇa and whether the modern Vasiṣṭha Siddhānta was compiled by Viṣṇucandra, will be discussed later on.

---

*See Introduction page LX of Pañcasiddhāntikā by Dr. Thibaut

PULIŚA SIDDHĀNTA

A large part of the Pañcasiddhāntikā is devoted to the Puliśa Siddhānta It is stated in the 10th couplet of the first Chapter that Romaka's 'ahargaṇa' is very nearly equal to that of the Puliśa Siddhānta. Then follows the calculation of the place of the luminaries etc. and of the eclipses of the sun and the moon.

It has not at all been stated what the motions and places of Mars and other planets are according to the Puliśa Siddhānta ; but the last couplet states that "the planets have thus been described according to the Puliśa Siddhānta" and which shows that about 16 'āryās' in the end mention something from Puliśa Siddhānta about their direct and retrograde motions, and the rise and set of planets.

The elements pertaining to the Puliśa Siddhānta are found to be as follows :

खार्क (१२०) घ्नेग्निहुताशन (३३) मपास्य रूपाग्निवसुहुताशकृतैः (४३८३१) ।।
हृत्वा क्रमाद्दिनेशो मध्यः... ।। १४ ।।
अष्टगुणे दिनराशौ रूपेंद्रियशीतरश्मिभि (१५१) र्भक्ते ।।
लब्धा राहोरंशा भगणसमाश्च क्षिपेल्लिप्ताः ।। ४१ ।।
वृश्चिकभागा राहोः षड्विंशतिरेकलिप्तिकालुप्ताः ।। ४२ ।।

"(14) Multiply the ahargaṇa by 120, deduct 33, and divide by 43831 the result is the mean longitude of the sun in due order. (41) Multiply the ahargaṇa by 8 and divide the product by 151 ; the quotient indicates the degrees of Rāhu (i.e. the moon's ascending node) to which as many minutes have to be added, as there are complete revolutions. (42) This is a stanzas stating certain correction to be applied to the place of the moon's node as found according to the above rule. Apparently 25 minutes have to be deducted from that place. We do not know what is meant by "Vṛścika-bhāgā Rāhoḥ".

These couplets are found in the chapter following the one consisting of the first 25 āryās, and they form part of the passages attributed to the Puliśa Siddhānta. The elements derived from these āryās are as follows .—

The measure of the year	*365*d *15*gh *30*pal
Number of Sāvana days in one Mahāyuga .	1577916000
No. of revolutions of Rāhu	$232227\frac{65703915}{67946855}$
Period of Rāhu's one revolution . . .	*6794*d *41*gh *18*pal

This gives for the measure of the year a figure different from that of other Siddhāntas. Similarly, the period of the revolution of Rāhu (the moon's ascending node) is also somewhat different.

The Pañcasiddhāntikā mentions other things from the Puliśa Siddhānta which include the question of true places of the sun and the moon. It describes the method of finding 'carakhaṇḍas' (groups of ascensional differences) from the 'palabhā' (the noon shadow on equinoctial day), and calculating therefrom the length of the day ; terrestrial longitudes too have been considered.

The method of calculating the tithi and nakṣatra is similar to one of the present day. It includes the explanation of the 'karaṇas' and 'Mahāpātas' (or the parallels of the declination of the sun and the moon). The question of eclipses is also considered and the method is almost similar to that of other modern Siddhāntas. The study of the direct and retrograde motions of planets is similar to that described in the work entitled Khaṇḍakhādya. The study 'cara' (ascensional difference) quotes the following couplet.

यवनाच्चरजा नाडय: सप्ता (७) बंत्यास्त्रिभाग (१/३) संयुक्ता: ॥
वाराणस्यां त्रिकृति: (६) साधनमन्यत्र वक्ष्यामि ॥

"The Yavana mentions 7gh 20pal. as the 'cara' for Ujjayinī and 9 ghaṭis for Vārānasī. The method of calculating it, is described elsewhere".

The word mentions, as in Vedāṅga Jyotiṣa, dinamānavṛddhi, or the increase in the length of a day at the end of Udagayana as compared with that at the end of the Dakṣiṇāyana. According to the sayana almanac, the minimum and the maximum length of the day at Ujjayinī are *26*gh. *26*pal. and *33*gh. *34* pal. respectively; that is, the difference between the two amounts to 7gh. 8p. According to the Grahalāghava these values are 26gh. 21p. and 33gh. 39p respectively and the difference is equal to 7gh. 18p. These have been calculated by assuming 5-8 as the palabhā for Ujjayinī. Pandit Bāpūdeva śāstri gives in his almanac, the maximum length of the day at Vārānasī to be 33gh. 56p. and the minimum length as 26gh. 4HP. The difference between the two comes to be 7gh. 52p. This has been calculated on the basis of 5-40 as the palabhā at Vārānasī. Assuming this very value for Vārānasī, the Grahalāghava calculation shows 8gh. 4pal. as the difference between the two lengths. Assuming 6-15 as the palabhā, one gets a difference of about 9 ghaṭis on the basis of Puliśa's 'Carakhaṇḍa' as given by the Pañcasiddhāntikā.

The third couplet in the Pañcasiddhāntikā shows that Lāṭadeva has written a commentary on the Pauliśa Siddhānta.

The author has neither seen nor heard of any Puliśa Siddhānta of any kind being available at present. Utpala has incidentally quoted about 35 couplets from the Puliśa Siddhānta as authority in his commentary on the Bṛhatsaṃhitā. They contain the number of revolutions and other important elements given by the Puliśa Siddhānta. Those couplets as collected in one place are, therefore, quoted below :—

अष्टाचत्वारिंशत्पादविहीना: क्रमात् कृतादीनां ॥ अंशास्ते शतगुणिता ग्रहतुल्ययुगं तदेकत्वं ॥

(The meaning is not quite clear)

"The number of years* in a Kṛta yuga is obtained by multiplying 48 by 100 and that in the successive Yugas is obtained after multiplying 100 the "number 48 diminished by its quarter (i.e. 12) successively".

This is a unit (ekatvam) to start with in the case of each kind of 'planetery' yugas.

[**Footnote by the translator :—*

Although the text quotes 'aṃśaḥ' as the word, the manuscript, which I could see by the kind permission of the local Scindia Institute, gives the word "abdaḥ", and the explanation therein shows that the Mahāyuga (which was rendered as the 'divine yuga' by the later astronomers) consisted of (4800+3600+2400+1200=12,000 years). According to the prevailing system, the year was of 4 kinds and consisted of 4 kinds of months, each of 30 days of the corresponding denomination].

"We get the number of suppressed days with the help of the number of solar days in the yuga and the difference (47800080) between the measures of the lunar and sāvana yugas. When all the four results can be obtained by means of the above figures, where is the need of remembering the results individually ? Whatever results we thus obtain, indicate the number of days in the Sāvana and other kinds of Yugas."

वेदाश्विवसुरसांतरलोचनदस्रै (२२९६८२४) खनिसूनुः ।।
अंबरगगनवियन्मुनिगुणविवरनगेंदुभिः (१७९३७०००) शशिसुतस्य ।।
आकाशलोचनेक्षणसमुद्रषटकानलै (३६४२२०) जीवः ।।
अष्टवसुहुतवहानल (?) यमखनगै (७०२२३८८) भार्गवस्यापि ।।
कृतरसशरर्तुमनुभिः (१४६५६४) सौरो; बुधभार्गवौ दिवाकरवत् ।।

"These verses give the number of revolutions which each planet makes in a yuga. Mars makes **2296824** ; Mercury's epicycle 17937000 ; Jupiter, **364220**; Venus's epicycle, **7022388** ; Saturn **146564** ; Mercury and Venus make revolutions equal to those of the Sun. "Atha kakṣamānāni":—Now are given the lengths of the orbits of planets :—

अथकक्षामानानि-आकाशशुन्यतिथिगुणदहनसमुद्रैर्बुधार्कशुक्राणां (४३३१५००)
इंदोः सहस्रगुणितैः समुद्रनेत्राग्निभिश्च (३२४०००) स्यात् ।।
भूसूनोर्मुनिरामछिद्रर्तुसमुद्रशशिवसुभिः (८१४६९३७) ।।
रुद्रयमाग्निचतुष्कव्योमशशांकै (१०४३२११) बुंधोच्चस्य ।।
जीवस्य वेदषट्कस्वरविषयनगाग्निशीतकिरणाद्यैः (५१३७५७६४) ।।
शुक्रोच्चस्य यमानलषट्कसमुद्रर्तुरसदस्रैः (२६६४६३२) ।।
भगणोर्कजस्य नवशिखिमुनींदुनगषटकभुनिसूर्यैः (१२७६७१७३९)
रविखवियन्नववसुनवविषयेक्षण (२५९८९००१२) योजनैर्भकक्षायाः ।।

"The lengths of planetary orbits in yojanas (i.e. 8 miles) are as follows :— Mercury, Venus and the Sun, **4331500** ; Moon, **324000** ; Mars, 8146937 ; Mercury's aphelion, 1043211 ; Jupiter 51375764 ; Aphelion of Venus **2664632** ; Saturn **127671739** ; Zodiac **259890012**".

इष्टग्रहकक्षाभ्यो यल्लब्धं चंद्रकक्षया भक्त्वा ।।
ता मध्यमा ग्रहाणां सौरादीनां कलाश्चांद्राः ।।
पंचदशाहतयोंजनसंख्या तत्संगुणोर्धविष्कंभः ।।
योजनकर्णार्धस्याद्युयोजनकर्णविधिना वा ।।

"Whatever is obtained after dividing the planet's orbital length by the moon's orbital length, is to be known as the planet's mean distance in lunar-minutes of arc. When this number is multiplied by 15, it gives the semi-diameter of the planet's orbit, which represents the planet's geocentric distance. This can otherwise be calculated from the geocentric radius of the orbit of the heavens (i.e. that of the celestial sphere)."

वसुमुनिगुणांतराष्टकषट्के (६८९३७८) दिननाथशुक्रसौम्यानां ।।
द्वादशबलषद्कोंद्रियशशांकमूर्ते (५१५६६) रजनिकर्तुः ।।

दस्राब्धिषद्करसनलोचनचंद्रै (१२९६६४२) क्षनिसूनोः ॥
रूपाग्निशून्यषट्काष्टिसंमितः (१६६२३१) स्याद्बुधोच्चस्य ॥
अष्टकवसुरसषण्मुनिशशांकवसुभिस्तु (८१७६६८८) जीवस्य ॥
वसुवसुशून्याष्टद्विकवेदै (४२८०८८) रपि भार्गवोच्चस्य ॥
एकार्णवार्थनवशशिदहनखदस्रै (२०३१९५४१) रविसुतस्य ॥
त्रिवसुरसद्विरसानलशशिवेदैं (४१३६२६८३) राक्षपरिधिकर्णार्धं ॥

"The semidiameters of planetary orbits in yojanas are given below :— **689378** *of the Sun*, Venus and Mercury, **51566** of the Moon ; **1296642** of Mars, 166231 of Mercury's aphelion ; 8176688 of Jupiter, 428088 of Venus's aphelion, 20319541 of Saturn and 41362683 of the Zodiacal belt".

वृत्ता चक्रवदवनिस्तमसस्पारे विनिर्मिता धात्रा ॥ पंचमहाभूतमया तन्मध्ये मेरुरमराणां
तस्योपरि ध्रुवः खे न द्वंद्वं पवनरश्मिमिक्ष्चक्रं ॥ पवनाक्षिप्तं भानामुदयास्तमयं परिभ्रमति ।
सर्वेजयिन उदक्स्था दक्षिणदिक्स्थो जयी शुक्रः ॥

"Beyond darkness has been created by God Brahmā, this earth, round like wheel, was made up of five main elements. In its centre stands the mountain Meru, the abode of gods, and the pole occupies a place in the sky just above it. The wheel of stars, being propelled by wind, and creating rises and sets, revolves, as if pulled by 'reins' of wind. (The words 'na dwandwan' are not clear). All planets when occupying the north give success and only Venus, when in the south gives success."

Although the Pañcasiddhāntikā does not explicitly state that the Puliśa Siddhānta in it postulated the Yugādi system, it appears from the couplets, which mention the intercalary months and suppressed tithis, that it did not postulate the Yuga system. Moreover Brahmagupta has blamed only Romaka on that account. This tends to show that the Puliśa Siddhānta of the Pañcasiddhāntikā did probably contain the description of the yuga-system. The Puliśa's statement as quoted by Utpala includes it. The 'sāvana māna' (i.e. civil measure) alluded to in the statement is termed as 'solar' in other works, and the solar measures in the former are termed sāvana by the latter. The measures of 'bhagaṇas' etc., as quoted by Utpala from the Puliśa Siddhānta, taking the meanings of the words 'sāvana' etc. as given by other works are given below :—

Revolutions of stars	1582237800
Revolutions of *the sun*	4320000
Sāvana days	1577917800
Revolutions of the moon	57753336
Revolutions of Moon's apogee (from Beruṇī)	488219
Revolutions of Moon's asc. node (from Beruṇī)	232226
Revolutions of Mars	2296824
Revolutions of Mercury's epicycle	17937000*
Revolutions of Jupiter	364220

*This is the number of the planets' conjunctions with the Sun.

Revolutions of Venus's epicycle	7022388
Revolutions of Saturn	146564
Civil Months	51840000
Intercalary months	1593336
Lunar months	53433336
Tithis	1603000080
Suppressed days	25082280
The Length of a year	365^{d}-15^{gh}-31^{p}-30^{vp}

This shows that the length of the year as given by the Puliśa Siddhānta of the Pañcasiddhāntikā and the Puliśa Siddhānta of Utpala are different. Thie means that the Puliśa Siddhānta of the Pañcasiddhāntikā is quite differenn from the Puliśa Siddhānta of Utpala. One more surprising fact is that Utpala himself has given the sentence as an 'extract' from the original Puliśa Siddhānta :—

खखाष्टमुनिरामाश्विनेत्राष्टशररात्रिपा: (१५८२२३७८००) ॥
भानां चतुर्युगेनैते परिवर्ता: प्रकीर्तिता: ॥

"The number of revolutions of the stars in one Caturyuga (Mahāyuga) is 1582237800."

It gives the number of revolutions of nakṣatras in a Mahāyuga. This tallies with the one mentioned in the couplets quoted above. Even then, Utpala has mentioned this as a quotation from the original Puliśa Siddhānta, and it is composed in the Anuṣṭup meter. This shows that there existed at the time of Utpala (śaka 888) two Puliśa Siddhāntas which were different from the one belonging to the Pañcasiddhāntikā group. Hence, the number of Puliśa Siddhāntas comes to be three. The first two couplets of the last 2½, out of those quoted by Utpala, describes the Universe in the manner in which it is found described in the modern Sūrya Siddhānta and other Siddhāntas ; the last half couplet refers to the conjunctions of planets. This shows that the Puliśa Siddhānta, composed in the Āryāmetre and existing in Utpala's time, must have been a complete work like other Siddhāntas. Similarly, the Puliśa Siddhānta belonging to the Pañcasiddhāntikā group also appears to have been a complete work from the detailed information cited from it above.

The numbers of revolutions and other elements in the Puliśa Siddhānta a quoted by Utpala, exactly tally with those of the Sūrya Siddhānta belonging, to the Pañcasiddhāntikā and given on a subsequent page. Similarly, all the measures, excepting the number of civil days and the numbers depending upon it, such as suppressed tithis etc. and the revolutions of Mercury and Jupiter agree with those given by First Āryabhaṭa.

Albiruṇī, the famous Muslim scholar and traveller, who had come to India with Mahmud of Ghazni, and stayed here from 1017 to 1030 A.D. and studied Indian sciences, particularly, the science of astronomy very critically remarks that the Puliśa-Siddhānta was compiled by Paulus-ul-Yunani or Paulus, the Greek, which means that the Hindus compiled it with the help of his work. Weber says that Albiruṇī could get in India only the Brahmagupta and the Puliśa Siddhāntas and none others.

युगणेर्कोष्टशत ८०० घ्ने विपक्षवेदार्णवे ४४२ र्कसिद्धांते ॥
स्वरखा-च्विद्विनवयमी २९२२०७ हृते क्रमाह्निदलेऽवंत्यां ॥ १ ॥
नवशतसहस्र ९००००० गुणिते स्वरैकपक्षांबरस्वरर्तू ६७०२१७ ने ॥
षड्व्योमेंद्रियनववसुविषयजिनै २४५८९९९६ र्भाजिते चंद्रः ॥ २ ॥
नवशत ९०० गुणिते दद्याद्रसविषयगुणांबरर्तुयमपक्षान् २२६०३५३ ॥
नववसुसप्ताष्टांबरनवाश्वि २९०८७८९ भक्ते शशांकोच्चं ॥ ३ ॥
शशिविषय ५१ घ्नानींदोः खार्काग्नि ३१२० हृतानि मंडलानि ऋणं ॥
स्वोच्चे दि १० घ्नानि घनं स्वरदस्रयमो २२७ हृते विकलाः ॥ ४ ॥

अध्याय ९

"Chap. 1, (14) According to the Saura (Siddhānta) there are in 180000 years 66389 intercalary months and 1045095 suppressed lunar days.

Chapter 9—(1) According to the Sūrya Siddhānta the mean place of the sun is found (i.e. in revolutions and signs etc.) by multiplying the ahargaṇa by 800, deducting 442, and dividing by 292207 successively; the place so found is for the midday at Avantī.

(2) Multiply the ahargaṇa by 900000, deduct 670217 and divide by 24589996 ; the result is the mean place of the moon.

(3) Multiply the ahargaṇa by 900, add 2260353, and divide by 2908789 ; the result is the place of the moon's *Ucca*.

(4) Multiply the revolutions of the moon by 51 and divide by 3120 ; deduct the result taken as seconds. Also, multiply the revolutions of the moon's *Ucca* by 10 and divide by 227 ; the resulting seconds are to be added to the moon's *Ucca*."

एष निशार्थेऽवंत्यां ताराग्रहणेर्कसिद्धांते ॥ तत्रेंदुपुत्रशुक्रौ तुल्यगती मध्यमार्केण ॥ १ ॥
भौमस्य शता १०० भ्यस्तं द्विरियमाग्निरित्रसागरै ४३३२३२ र्विभजेत् ॥
युगणं कुजस्य चंद्रा १ हृतं तु सप्ताष्टषड् ६८७ भक्तं ॥ २ ॥
सौरस्य सहस्र १००० गुणं ऋतुरसशून्यर्तुषड्कमुनिखेकैः १०७६६०६६ ॥
यल्लब्धं ते भगणाः शेषा मध्याग्रहाः क्रमेणैव ॥ ३ ॥
राशिचतुष्टय ४ मंशद्वयं २ कलाविंशतिर्वसुसमेताः २८ ॥
नववेदा ४९ श्च विलिप्ताः शनेर्धनं मध्यमस्यैवं ॥ ५ ॥
अष्टौ ८ भागालिप्तांश्च ९ खमक्षी २० गुरौ विलिप्ताश्च ॥
क्षेपः कुजस्य यम २ तिथि १५ पंचत्रिंशच्च ३५ राश्याद्यः ॥ ६ ॥
शत १०० गुणितं बुधशीघ्रं खरनवसप्ताष्टभाजिते ८७९७ क्रमशः ॥
अत्रार्धपंचमा ४।३० स्तत्पराश्च भगणाहृताः क्षेप्याः ॥ ७ ॥
सितशीघ्रं दश १० गुणिते युगणे भक्ते स्वरार्णवाश्वियमैः २२४७ ॥
अर्धेकावधा देया विलिप्तिका भगणसंगुणिताः ॥ ८ ॥

सिंहस्य वसुयमांशाः २८ शरदवो १७ लिप्तिका शशीघ्रधनं ॥
शोध्याः सितस्य विकलाः शशिरसनवपक्षगुणदहनाः ३३२९६१ ॥ ९ ॥

अध्याय १६.

"(1) The determination of the mean places of the smaller planets for midnight at Avantī is, according to the Sūrya Siddhānta, as follows :— Mercury and Venus have the same motion as the mean sun.

(2) For Jupiter, multiply the ahargaṇa by 100 and divide by 433232. For Mars multiply the ahargaṇa by one and divide by 687.

(3) For Saturn, multiply the ahargaṇa by 1000 and divide by 10766066. The quotients are the entire revolutions ; from the remainders, the mean places of the planets are ascertained in signs, degrees and so on.

(4) For each revolution of Jupiter 10 'tatparas' (i.e. sixtieth parts of seconds) have to be deducted. 14 'tatparas' are to be added for each revolution of Mars ; five have to be deducted for each revolution of Saturn.

(5) Four signs, two degrees, twenty-eight mirutes and forty-nine seconds have to be added to the mean place of Saturn.

(6) Eight degrees, six minutes and twenty seconds constitute the additive quantity for Jupiter. For Mars that quantity amounts to two signs fifteen degrees and thirty-five minutes.

(7) For the 'śighra' of Mercury, multiply the ahargaṇa by 100, and divide by 8797. Add the product of the completed revolutions, and four and a half 'tatparas'.

(8) For the 'śighra' of Verus, multiply the ahargaṇa by 10 and divide by 2247. Add ten and a half seconds, multiplied by the revolutions.

(9) Twenty eight degrees of Leo (i.e. 4 signs plus 28 degrees) and seven teen minutes are the additive quantity for the 'śighra' of Mercury. From the 'śighra' of Venus 332961 seconds are to be deducted".

The first two couplets above give 365d-15gh-31pal-30vip as the measure of the year, and assuming the Kaliyuga to have commenced on Thursday, at midnight (when the longitudes of the sun and the moon were *nil*), the mean. Sun's entry into Aries in Śaka 427 falls on Sunday, the 14th tithi of Caitra, dark-half at 48gh-9pal. (The mean longitude of the sun was zero at the moment). The couplet "dyugaṇerko...." gives $11^s\, 29^\circ\, 27'\, 20''$ as the mean position of the sun at the epoch, and the couplet clearly states it to be true for the noon at Avantī, but what day it refers to is not stated therein. The mean longitude of the sun for the noon of Sunday, the 14th tithi of Caitra, dark half, as calculated for the moment 33gh-9p, before the mean sun's entry into Aries, tallies exactly with the epochal position given. This shows that the Sūrya Siddhānta of the Pañcasiddhāntikā has assumed the commencement

of the yuga at midnight and that it postulates the Yuga system. These conclusions prove* to be true from the fact that the figures for the revolutions of planets as giver below agree with the planetary positions calculated on the assumption of the beginning of the Kali yuga at midnight.

The figures as calculated from the Couplets quotea above are as follows —

	a	gh	pal	vipal
The length of the year	365—	15—	31—	30

In a Mahāyuga (i.e. **4320000** *years)*

The No. of revolutions of		The No. of revolutions of	
The stars . . .	1582237800	Jupiter . . .	364220
The Sun . . .	4320000	Venus . . .	7022388
Sāvana days . . .	1577917800	Saturn . . .	146564
Moon's revolutions .	57753336	Solar months . .	51840000
Revolutions of Moon's apogee	488219	Intercalary months .	1593336
Moon's asc. node . .	..	Lunar months . .	53433336
Revolutions of Mars .	2296824	Tithis . . .	1603000080
Revolutions of Mercury .	17937000	Suppressed days .	25082280

The epochal positions as 'emerging' from the above couplets (i.e. the positions at the epoch, calculated on the basis of the Sūrya-Siddhānta of Pañcasiddhāntikā) are as follows —

	s	°	′	″	
Sun	11	29	27	20	These positions are true for the noon of Sunday, the 14th tithi of the dark half of Caitra, śaka 427 (elapsed).
Moon	11	20	11	16	
Moon's Apogee .	9	9	44	53	

*Assuming at first that the yuga commenced on Thursday at midnight and adjusting planetary positions true for the moment, and then, arguing on the basis of the agreement of the two that the assumption was correct, appear like "arguing in a circle". But one is forced to follow this method in the case of many problems in astronomy when nothing certain is known about them in the beginning. I have stated above only the final results obtained after the full consideration of the facts embodied in the above couplets. But only experienced persons can realize what pains I must have had to take over before arriving at the conclusion, and in how many ways I had to make different assumptions and to attempt the verification of their truth. When in August 1887 and Feb. 1888, inspite of several difficultes enumerated below, I could establish a correspondence between the multipliers and divisors with the epochal elements, and could particularly explain how the planetary positions mentioned by the Bhāswat karaṇa and Khaṇḍakhādyaka almost agree with the figures given by the Sūrya Siddhānta of the Pañcasiddhāntikā, and could establish a certainty about the three works, my delight knew no bounds. The difficulties were (i) the Pañcasiddhāntikā was compiled about 1400 years ago (ii) it had no commentary, (iii) the copy which I had obtained was very inaccurate (iv) suspicion about the reliability of the words denoting the numerical quantities indicated by them and written below, in the above couplets, since the manuscript was incorrect, and (v) the fact that the figures indicating the length of the year and revolutions of planets do not fully agree with any of the modern siddhāntas. It must, however, be recorded here that this research does not deserve any more importance than what it is worth from the historical point of view. I enjoyed some more such moments of delight while writing this work—The author.

	s	°	′	″	
Moon's asc. node .	..	..	..	..	
Mars . . .	2	15	35	4	
Mercury . .	4	28	17	7	The epochal positions of Mars and other planets are true for the midnight of Sunday, the 14th tithi of the dark half of Caitra.
Jupiter . . .	0	8	6	20	
Venus . . .	8	27	30	35	
Saturr . . .	4	2	28	49	

The motion and position of Rāhu (moon's asc. node) has been mentioned in the 5th couplet of the 9th Chapter, but the couplet is unintelligible. The first couplet of the 16th Chapter clearly states that the epochal positions are true for the midnight, but which day it refers to has not been mentioned. The positions of planets, calculated on the basis of planetary revolutions mentioned above and true for the midnight of Sunday, the 14th tithi of the dark-half of Caitra, i.e. a moment 3gh-9 palas before the mean Sun's entry into Aries, completely agree with the epochal positions given by the couplets. The 6th couplet gives the 'kṣepakas' (epochal positions) for Mars, and the figures for seconds (of arc) appear to have beer left out from it. The 9th couplet mentions Mercury's positions which contain no figures for seconds ; and the position of Venus is given shorter by four seconds. But there would be ro harm if it be said tnat the difference of a few seconds in the epochal positions should be regarded as negligible.

The above mentioned figures denoting revolutions and the length of a year do not agree with the corresponding measures of revolutions etc. given by the modern Sūrya Siddhānta. This shows that the Sūrya Siddhānta of Pañcasiddhāntikā and the modern Sūrya Siddhānta differ from each other in respect of elements and revolutions etc. That the former is older than the latter is evident from the fact that Varāhamihira has incorporated only the former. The date of the latter will be considered later on.

The above figures from the Sūrya Siddhānta of the Pañcasiddhāntikā completely agree with those from the Puliśa Siddhānta and cited from Utpala above. It will be shown later on that Brahmagupta has adopted in his work, "Khaṇḍakhādyaka", all these elements except those for the Moon's Apogee and the Ascending Node. It will be seen that all the elements from the Sūrya Siddhānta of the Pañcasiddhāntikā, except those for the length of the year and the revolutions of Mercury and Jupiter, completely agree with those of the Siddhānta of Āryabhaṭa which are given later on. It will be shown*

*Jupiter's 'Kṣepaka' (epochal position) as given by Bhāsvatīkaraṇa agrees with the calculated result, if 364224 be assumed as the Jupiter's bhagaṇas (revolutions) instead of 364220 ; but this (364220) can be proved to be the Jupiter's 'bhagaṇas' according to Pañcasiddhāntikā, from the multipliers and divisors, as mentioned in the first half of the 2nd couplet of the 16th Chapter, given above. Accepting 364224 as the correct number, 100 revolutions require 433227 days. Utpala's Puliśa Siddhānta and the modern Sūrya Siddhānta give 364220 as the number of Jupiter's revolutions and on the basis of this very number one can arrive at the Jupiter's 'Kṣepaka' according to Khaṇḍakhādyaka. The Siddhānta of Āryabhaṭa states 364224 to be Jupiter's bhagaṇa ; and Varāhamihira, while describing in the 8th chapter of Bṛhatsaṃhitā, the method of finding the 'Barhaspatyasamvatrsa' (Jovian year) for any śaka year, assumes a Kṣepaka which can be obtained by assuming 364224 as the Jupiter's bhagaṇa.

further, that the mean planetary positions for the epoch, have been obtained from the Bhāsvatīkaraṇa, by borrowing from the Sūrya Siddhānta of Pañca-siddhāntikā, the elements for all planets, except Jupiter, and applying the corrections suggested by Varāhamihira separately, in the 10th and 11th couplets of the 16th Chapter of the Pañcasiddhāntikā.

Albiruṇī states† that the Sūrya Siddhānta was compiled by Lāṭa ; but, the Sūrya Siddhānta of the Pañçasiddhāntikā is not compiled by Lāṭa. Prof. Weber says‡ that the Sūrya Siddhānta must have some connection with Ptolemy. Both these points will be discussed later on in the course of the study of the modern Sūryasiddhānta.

The above study of the five Siddhāntas, includes that of their dates also. They are, Paitāmaha, Vāsiṣṭha, Pauliśa, Saura, and Romaka as seen in their chronological order. It seems that Romaka belongs to a pre Śaka period and the remaining four were older than it.

THE PAURUṢA (HUMAN) AUTHORS OF ASTRONOMICAL WORKS BEFORE ŚAKA 420

The Pañcasiddhāntikā mentions names of some authors of astronomical works and no other source than this is available for obtaining any information about authors or writers of works before Śaka 420.

The followirg references are found in the Pañcasiddhāntikā—

पंचम्यो द्वावाद्यौ (पौलिशरोमकसिद्धांतौ) व्यारव्यातौ लाटदेवेन ॥ ३ ॥

अ० १.

लाटाचार्येणोक्तो यवनपुरे चास्तगे सूर्ये ॥ रव्युदये लंकायां सिंहाचार्येण दिनगणोभिहितः ॥ ४४ ॥

यवनानां निशि दशभिर्गतैर्मुहूर्तैश्च तद्गुरुणा ॥ लंकार्धरात्रसमये दिनप्रवृत्तिं जगाद चार्यभटः ॥ ४५ ॥

भूयः स एव सूर्योदयात् प्रभृत्याह लंकायां ॥

अ० १४.

(3) The first two of the five (viz. Pauliśa and Romaka) have been described by Lāṭadeva.

(44 & 45) The purport of these very important lines from the 14th chapter is as follows—Lāṭācārya has enjoined the calculation of ahargaṇa from the moment of sunset (on the horizon) of Yavanapur.

(The moment of sunset at Yavanapur coincides with that of midnight at Laṅkā). Siṃhācārya has enjoined the calculation of ahargaṇa from the sunrise at Laṅkā, while his preceptor enjoins the adoption of ten muhūrtas (i.e. 20 ghaṭis) in the night for the calculation of ahargaṇa in the Yavana country. Āryabhaṭa after stating the commencement of the day as from the midnight at Laṅkā, has again defined the day as begining from the sunrise* there. The name of Siṃha's preceptor referred to here is not known. Here is a reference quoting some more names :—

†See Dr. Kern's Preface to the Bṛhatsaṃhitā and page 2 of the Translation of the Sūrya Siddhānta by Burgess.

‡See page 3 of Translation of Sūrya Siddhānta by Burgess.

*Āryabhaṭa's reference of the commencement of a day at sunrise at Laṅkā will be given later on. The reference of the day commencing at midnight in Laṅkā is not found in the Āryabhaṭīya.

प्रद्युम्नो भूतनये जीवे सौरे च विजयनंदी ॥ ५६ ॥

शेवटचा अध्याय.

"Praoyumna broke down in the matter of Mars and Vijayanandi in the matter of Jupiter ano Saturn..................".

These are the names mentioned by the Pañcasiddhāntikā. Of these, an account of Āryabhaṭa will be given later on. All these names occur in Brahmagupta's Siddnānta also. All of them have been criticised by Brahmagupta in some way or other. We do not come across any mention of their merits. The statement that Śrīṣeṇa has adopted some elements from Lāṭa in his work, Romaka, has already been given above. Varāha remarks that Lāṭa has commented upon the Puliśa and Romaka Siddnārtas and this commentary cannot possibly contain his own views. This shows that Lāṭa must have compiled a separate work. Brahmagupta elsewhere observes :—

श्रीषेणविष्णुचंद्रप्रद्युम्नार्यभटलाटसिंहानां ॥ ग्रहणादिविसंवादात् प्रतिदिवसं सिद्धमकृतत्वं ॥
४६ ॥

†अंकचितिविजयनंदिप्रद्युम्नादीनि पादकरणानि ॥ यस्मात्तस्मात्तेषां न दूषणान्यत्र लिखितानि ॥
५८ ॥

अध्याय ११

It shows that Lāṭācārya had perhaps compiled a work. Similarly Siṃhācārya also had compiled one. Even Varāhamihira has remarked in one of the above mentioned couplets that Pradyumna broke down in respect of Mars and Vijayanandi about Jupiter and Saturn. The 'Karaṇa' works of both these authors are described as 'pādakaraṇa'. In one of the couplets given before, Brahmagupta says that Śrīṣeṇa has borrowed the Vijayanandi's pādas. This remark is unintelligible, and it is not clear if 'pāda' means a 'yugapāda'.

Anyway, it appears that Lāṭa*, Siṃhā, Pradyumna and Vijayanandi were authors of astronomical works who lived before Śaka 420.

THE FIVE MODERN SIDDHĀNTAS

(SŪRYA, SOMA, VASIṢṬHA, ROMAŚA AND ŚĀKALYA'S BRAHMA SIDDHĀNTAS)

The Pañcasiddhāntikā included all the siddhāntas excepting the Somasiddhānta, and it has already been shown that these siddhāntas and those which are to be considered now, are different, and this fact will be further corroborated by the discussion which will follow. The siddhāntas whose study is going to be made now are extant present and are different from those belonging to the Pañcasiddhāntikā group ; and that is why the epithet 'modern' has been applied to them. Although there is no definite evidence to show that there existed or still exist two Somasiddhāntas, still it is completely

†The word 'aṅkaciti' also seems to be a proper noun.

*After studying the contents of Vedāṅga Jyotiṣa and the above discussion, it will be seen that there is no sense in the suspicion expressed by Weber that Lāṭa msut be the same as Lagadha.

similar to the other four, and it is desirable to study it (i.e. Somasiddhānta) along with them. After a general discussion of the five siddhāntas, each of them will be considered separately later on.

APAURUṢEYA *i.e.* DIVINE

All the five siddhāntas declare themselves to be divine and they are actually so regarded. No other siddhānta is regarded as divine except these five siddhāntas, and some or all of the siddhāntas from Pañcasiddhāntikā, and Viṣṇudharmottara Brahmasiddhānta. Even if there were some other siddhāntas regarded as divine before, they are not at present available. The Vyāsasiddhānta, Garga siddhānta, Nārada siddhānta and Parāśara siddhānta are also divine ; but these should better be called Saṃhitās than Siddhāntas. The author does not think that a work known after Vyāsa and others, and dealing with subjects usually found in siddhānta and in their usual order can be available at present ; and if there be one, he has neither seen nor read it. The number of revolutions and other elements are quoted by European scholars from the Parāśara Siddhānta ; but these are given in one of the Chapter of second Āryasiddhānta as taken from Parāśarasiddhānta. The siddhānta as an independant work is not available. This point will be considered at greater length in the study of the second Āryasiddhānta. The Brahma-siddhānta by Viṣṇudharmottara (Puraṇ) will later on be discussed at greater length. The most ancient of the 'pauruṣa' (i.e. human) siddhāntas is the first Āryasiddhānta. Its date is Śaka 421. All the siddhāntas enumerated at the top may not necessarily be more ancient than this. It is, however, felt that at least one of them must be older than that. Because all are similar to one another, and because these are also regarded as divine, it will be proper to describe them first, just after the discussion of Pañcasiddhāntikā.

At first the numbers of revolutions and other elements mentioned by all the five siddhāntas, which are the same in all the works, are given below :—

The elements given by the Sūrya, Soma, Vasiṣṭha, Romaka Siddhāntas and Śākalya's Brāhma Siddhāntas :—

Years spent in Creation	17064000
Number	*In a Mahāyuga*
Revolutions of 'stars'	1582237828
Revolutions of the Sun	4320000
Sāvana days	1577917828
Revolutions of the Moon	57753336
" Moon's apogee	488203
" Moon's anomaly	57265133
" Moon's node	232238
" Mars	2296832
" Mercury	17937060
" Jupiter	364220
" Venus	7022376

Revolutions of Saturn	146568
Lunar months	53433336
Lunar tithi	1603000080
Solar months	51840000
Intercalary months	1593336
Suppressed tithis	25082252

Planet	*No. of revolutions in a Kalpa*	
	Aphelion	Node
Sun	387	..
Mars	204	214
Mercury	368	488
Jupiter	900	174
Venus	535	903
Saturn	39	60

THE YUGA SYSTEM

These give 17064000 as the number of years elapsed after Creation, and some thing must be stated about this. Some idea about the yuga system has already been giver in the Introduction. According to Brahmagupta and his followers, the creation took place at the beginning of Brahma's day, and at that moment, *i.e.* in the beginning of Kalpa, all the planets, their aphelia and nodes were conjoined together with the first point of Aries. According to Modern Sūryasiddhānta and other siddhāntas which follow it, the world was not created at the beginning of Kalpa but Brahmā required 47400 divine years that is a period equivalent to 39½ Kali yugas for creating the world. All planets, their aphelia and nodes came together when so much time elapsed after the beginning of Kalpa, and then the planets began to move. Āryabhaṭa II holds almost the same view. He, however, supposed a different number for the period elapsed in Creation, which will be mentioned later on. Similarly, the views of Āryabhaṭa I, will be given later on. We have no means to know the views of Sūrya and other Siddhāntas of the Pañcasiddhāntikā.

According to the modern Sūryasiddhānta, all planets are supposed to come together by mean motion, in the beginning of the present Kaliyuga. Similarly, all the planets were together, at the end of the Kṛtayuga when the Sūryasiddhānta was compiled. The numbers denoting revolutions of planets in a Mahāyuga are divisible by 4. Hence, each planet makes complete revoultions in a period equivalent to 2½ (*i.e.* 10÷4) Kaliyugas, and therefore, all planets will come together after each such periods of 2½ Kaliyugas. A period equal to 4567 Kaliyugas passed after the beginning of Brahma's day till the beginning of the present Kaliyuga. This number is not divisible by 2½ ; hence, all the planets cannot be shown to be together at the beginning of Kalpa unless it be assumed that some years must have been spent in creation. Supposing

that a period equal to 39½ Kaliyugas passed in creation, the period elapsed between the setting in motion of planets to the commencement of the present Kaliyuga comes to be (4567—39½=4527½) Kaliyugas. This number is divisible by 2½. Hence, after supposing that all planets were together in the beginning of creation, they will be found to be together in the beginning of the present Kaliyuga and at the end of Kṛtayuga before it. Similarly, starting with the assumed number of revolutions in a Kalpa, the aphelia and nodes will be seen to be together only in the beginning of creation and at no other time.

GENERAL DESCRIPTION

Of these five Siddhāntas, the Sūryasiddhānta is very famous. It has been commented upon by many, and it has been even printed and published. The remaining four Siddhāntas are not much known. Of them, the Vasiṣṭha siddhānta, consisting of 94 couplets in 4 Chapters, has been published by Vindhyeśvarī Prasād Śarmā of Vārānasī. No other siddhānta in printed form has come to my notice. I have, with great difficulty, procured copies of all the four siddhāntas. There is a manuscript in the Deccan College collection entitled 'Vasiṣṭhasiddhānta-Bhūgolādhyāya' which is different only in wording from the Vasiṣṭhasiddhānta published at Vārānasī, (D.C. collection No. 78 of 1869-70 A.D.). It has two chapters which contain 133 verses in all. Of them, the first chapter, consisting of 121 couplets, contains a description of the Universe as in other siddhāntas. The second chapter gives only the measures of orbital lengths. The numbers of revolutions and other elements in both the Vasiṣṭha Siddhāntas are exactly the same ; and hence it would be correct to say that there is only one Vasiṣṭha Siddhānta and not two. This point will be discussed to some extent later on.

It has no doubt been remarked above that the numbers of revolutions and other elements are the same in all the above mentioned five siddhāntas ; but a slight departure was noticed which ought to be mentioned. A manuscript copy of the printed Vasiṣṭha Siddhānta is kept in the Deccan College collection (under No. 36—1870-71) and the following couplet is found in the first Chapter :—

नृपेषु सप्तवह्नय (*द्वि?) यमेभेषुधरोन्मिता: (१५८२२३७५१६) ॥
भ्रमा: पश्चिमायां च दिशि स्युर्वै महायुगे ॥ १७ ॥

"The number of revolutions of '*stars*' in a westerly direction is 1582237516 in one Mahāyuga."

The number of sāvana days in a Mahāyuga, as deduced from the number of revolutions of '*stars*' mentioned in this couplet, prove to be 1577917516, which gives 365^{d}-15^{gh}-31^{p}-15^{vp}-$48\dagger^{vp}$ as the length of the year. This measure is different from that of all other Siddhāntas. But this verse is not found in the book printed in Vārānasi. Even the second version of Vasiṣṭha Siddhānta referred to above (Deccan College collection, No. 78 of 1869-70) does not give the number of revolutions of stars. Again, the Siddhāntas†, which have been mentioned by Kamalākara (S. 1580), the author of Siddhānta-tatvaviveka as being quite similar to Sūryasiddhānta include even this very Vasiṣṭhasiddhānta. It appears from this that the couplet given in the Deccan College copy is interpolated, and that is why the numbers of revolutions and other elements in the Vasiṣṭhasiddhānta have been mentioned as bearing a resemblance with those of other Siddhāntas.

*The 8th letter is missing in this copy ; there must have been some letter denoting the number 2, and hence, I have inserted 'dvi' as the letter.

†See Chapter on "bhagaṇa māna" verse 63.

THE DATE

Let us consider in a general way the dates of these five Siddhāntas.

Bentley has found out a method of determining the date of compilation of a work on astronomy and from it he has fixed 1091 A.D. or Śaka 1013 as the date of the modern Sūrya Siddhānta. The method is as follows :—

To calculate the mean positions of planets with respect to the sun from the formulae given by the siddhānta whose date is to be found, and then after comparing them with the corresponding mean positions calculated from modern European books on astronomy, to see for what date, the planetary positions, as given by the siddhānta prove to be true in the case of each planet, and then to fix up the date of the siddhānta by adopting the average date. This method appears to be correct at first sight, and there can be no mistake if we accept Bentley's assumptions. But it is wrong to follow this method as can be seen from all considerations and the dates found out on that basis will not be reliable. The reasons are as follows :—Bentley's big mistake lies in the fact that he compared the mean places of planets calculated from the correct European tables, with those obtained from the Hindu astronomical works. But the mean planets cannot be seen in the heavens ; what is meant is that the planets will be seen to occupy those positions in the heavens which are found as true longitudes and not as mean. Whenever the Indian astronomers compiled their original works or found that the planets did not occupy places as indicated by their original works, they rectified their original works by applying suitable corrections (bījasaṃskāra)as applicable at their time. They must have done this with the help of observed positions, i.e. the places which they saw the planets actually occupying in the sky. The difference between the mean and the true place of a planet may be termed as 'phalasaṃskāra'' (equation of centre). If the value of this 'phalasaṃskāra' and the method of applying it be the same in the European and Hindu works, there would be no harm if the method of finding the date of a work on the basis of mean place be followed ; but it is not so. The 'phalasaṃskāra' to be given to the Sun is never less than 2° 10′ according to any Indian work while that according to the European works it is about 1° 55′ at present ; and this equation is not always the same. The authors of European works have proved that this equation was 2° 10′ at 3000 B.S. (before Śaka), but is gradually decreasing. The Moon's equation according to the Hindu works is about 5°, while according to European works it sometimes comes to 8°. The equation adopted by the Hindus is very erroneous. The figures denoting equations for other planets also are somewhat different. Similarly, the methods of finding the true place from the mean place and the elements for the 'mandocca and śighrocca' (aphelia) are different in the two kinds of works. Hence, it should not be taken to be a rule that even if the mean longitudes of planets, as calculated from the Hindu as well as the European works agree, that will result in the same figure for true place, and conversely, it cannot be said that a similar figure for the true place obtained from both will not necessarily give the same figures for the mean longitudes. Similarly, whatever difference be found in the two will not be found to follow the same law for all times to come. If under a particular case, similar values

of mean longitudes calculated from the two, be seen to yield similar figures for the true longitudes as well, they will be found to give different value in another case. For instance, if the mean and true places of Saturn, in Leo, be found to be the same figures according to both the works, it is not certain that similar results will be obtained for the Saturn in Scorpio. Hence, the variation in values of the equation of centre and that in the methods of finding them, would be found to lead to a variation of some centuries, even when the variation in the values of equations as found from the two works be very small. For instance, the following errors were noticed in the planetary position according to the modern Sūrya Siddhānta in the years noted below and as found by Bentley :—

	538 *A.D.*			1091 *A.D.*			*Correct year A.D.*
	°	′	″	°	′	″	
Moon*	—0	18	30	—0	0	11	1097
Mars	+2	26	30	+0	58	29	1458
Jupiter	—1	21	47	+0	41	14	906
Saturn	+1	50	10	—1	4	25	887

This shows that the error in the place of Mars in 538 A.D. was about 2½° and in those of others less than 2°. The error in the case of the Moon was extremely small. The places of all planets can possibly be found to be the same as the true places calculated by European tables and true for some moment during some particular revolution of those times ; that is, in other words, they can prove to be most accurate ; and hence it can be said that if the places of planets given by the Sūrya Siddhānta† agreed with those calculated from European tables for some date during the decade near about 538 A.D. ; then the Sūrya Siddhānta can be said to have been compiled about the year 538 A. D.. The compilation of original works of the Hindus or the corrections applied to them must have been based on the experience of at least 25 or 30 years ; and there are no means to know which planets were observed, on what dates and how, during this period. Hence, the method of determining of the date of compilation of a work according to Bentley's method is not faultless. Prof. Whitney has pointed out some of the drawbacks of Bentley's method, but has not pointed out the above very important and main drawback.

Bentley himself has considered the pros and cons of this method, but has not considered these objections.

Another point is that Bentley, while comparing the places of planets, has only calculated their distances from the Sun, but has not considered the error in the Sun's place as given by the Indian works, and which has crept in because of a small error in the length of the sidereal year adopted by our works. Prof. Whitney has pointed out that the consideration of this point will show that the Sun's place given by the Sūrya Siddhānta would be for the year 250 A. D. The

*When the planet's place is seen to be in advance of that obtained by European tables, the variation is indicated by plus (+) sign, and when it is behind, it is denoted by Minus (—). The error in the case of Mercury and Venus exceeded 3° and hence, the difference has not been shown here.

†It is sure that if the positions of all planets be calculated from both the works for different dates during 5, 10 or perhaps 30 years, it can be shown that the planetary places do agree for a particular date ; but the author has not done the calculation, since it involves much time and labour.

Indian authors could possibly have determined the corrections (Bījasaṃskāra)* to be applied to planets by two methods. One method of determining the correction for a planet is by observing its conjunction with stars, and the second is by observing its place by the '*Nalikā*' *instrument*. The length of a year adopted by our works which is nearly equal to that of the sidereal year but actually exceeds it by about 8 palas and this (variation) leads to a gradually increasing error in the longitudes of stars. The error at present is about 4½ degrees. (The difference in the Paṭawardhan's almanac and other nirayaṇa almanacs is due to this fact). Hence, if the corrections were determined from the conjunction of the planet with a star, it is bound to err, because the place of the star with which the planet was conjoined, was erroneous, and the date of compilation of work found on this basis must also err. The second method is that of observing a planet by the '*nalikā*' *instrument*. These methods of observation necessitate the conversion of the planet's place into a tropical (sāyana) form ; and although the adopted motion for the equinox is somewhat erroreous, the correction is not likely to go very wrong because the time taken by a planet or the sun to come to equinox does not differ much. Hence, becuase the corrections have been determined by this method, the date of compilation of a work, as found by Bentley's method of comparison of errors in planetary places with respect to the sun, can be accepted ; but the time when the sun, according to our works is found to come to the equinox, is somewhat erroneous. Because of this and also because the correction can possibly have been erroneous to the extent to which the observed results would be approximate, the date of compilation of a work can also be erroneous. The third point to consider is that, if it be supposed that Bentley's method is correct, it will be proper to use his method, if the author of the work, whose date is to be determined, has given the positions of planets by actual observation. But it will be of no use to apply the method, if the author has incorporated in his work the planet's places exactly as they are given in another work. If the correction given by Bhāskarācārya in his work be set aside, the elements of revolution etc. given by him are exactly the same as those given by Brahmaguptasiddhānta, and hence, the date of compilation of both these works will, by Bentley's method, come to be the same ; but the fact remains that Bhāskarācārya compiled his work, "Śiromaṇi", 522 years after Brahmagupta's Siddhānta. The correction given by Bhāskarācārya's work is found even in Rāja Mṛgāṅka, a work of Śaka 964. (More discussion about this will be given later on.) Hence, the dates of Rāja Mṛgāṅka (Śaka 964), Siddhānta Śiromaṇi (Śaka 1072) or of Karaṇakutūhala (Ś. 1105) will come to be the same by Bentley's method.

Bentley's method proves useless if the dates found by it are compared with the actual dates: The author attempted to apply the method in the case of the Sūrya Siddhānta of the Pañcasiddhāntikā and the first Āryasiddhānta and these are the inferences :—

*If it is found that the place of a planet as calculated from a Siddhānta does not agree with the observed place, it is decided to apply suitable correction to the motion and place of the planet as given by the work and this correction is known as 'Bīja'.

	The year when the planet according to Sūryasiddhānta would be correct	The year when the planet according to first Āryasiddhānta would be true
	Śaka	Śaka
Moon	520	468
Moon's apogee	482	482
Moon's asc. node	—	523
Mars	457	457
Mercury	93	734
Jupiter	772	480
Venus	409	409
Saturn	574	574
	3307÷7=472	4127÷8=516

This leads one to infer* that the Sūrya Siddhānta of Pañcasiddhārtikā was compiled in Śaka 472 and the first Ārya Siddhānta in Śaka 516. But it is beyond controversy that the first Ārya Siddhānta was compiled in Śaka 421 and it has also been shown before that the Sūrya Siddhānta of Pañcasiddhārtikā must have belonged to a period much earlier than Śaka 421. Bentley† has determined 1288 A. D. (Śaka 1210) as the date of the Ārya Siddhānta consisting of 18 chapters (i.e. the second Ārya siddhānta) and 1384 A. D. (Śaka 1306) as that of the Parāśara siddhānta ; but reference to some subjects in the second Ārya Siddhānta is found in the Siddhānta Śiromaṇi. This shows that the second Ārya Siddhānta must belong to a period earlier than Śaka 1072 A. D. and references to Parāśara Siddhānta also are found in the second Ārya Siddhānta. (More discussion about this will follow later on).

This will clearly show that the dates found by Bentley are not at all reliable and that the date of the Sūrya Siddhānta (viz. Śaka 1013) determined by Bentley is not worth considering.

Let us, therefore, independently consider the matter of dates of the five Siddhāntas.

Brahmagupta observes,

अयमेव कृत: सूर्येंदुपुलिशरोमकवसिष्टयवनाद्यै: ।। ३ ।।

अध्याय २४

"This very Siddhānta has been compiled by Sūrya, Indu, Puliśa, Romaka, Vasiṣṭha, Yavanācārya and others".

The Indu Siddhānta, mentioned in this, is the Soma Siddhānta itself. It shows that there existed a Soma Siddhānta before the time of Brahmagupta. No evidence is available to show that there existed some time before, a Soma Siddhānta, different from the Soma Siddhānta now available. No such Siddhānta is either available at present, or there is no evidence of its availability. Where then is the harm, if we say that, in the absence of any evidence

*Places of planets to be calculated from European tables have been calculated from the Keropant's Planetary Tables. If more accurate table would be followed, a variation of only 5 to 10 years may possibly occur.

†See Bentley's work (1823 A.D.) Part II, Section III.

time (principles of science of astronomy). God Madhusūdana who is proficient in this science, appreciating the good motives of Vasiṣṭha and being pleased with them both, gave them away the science, as a reward for penance. He uttered the words of Science through the two mouths (Vasiṣṭha and Romaka).

Even though these contain certain errors, the verses show that Romaka and Vasiṣṭha are both associated with the modern Romaka Siddhānta. The Romaka Siddhānta existing at the time of Brahmagupta had definitely a support from Vasiṣṭha (siddhānta). Hence, an inference can be drawn that Śrīṣeṇa's Romaka and Viṣṇucandra's Vasiṣṭha, existing in the time of Brahmagupta, are the same as the modern Romaśa and Vasiṣṭha Siddhāntas. The modern Romaśa Siddhānta does not mention Śrīṣeṇa's name and the name of the Siddhānta has been maintained, through an imaginary sage Romaśa. It, therefore, seems probable that the modern Romaka may be different from Śrīṣeṇa's Romaka in respect of its wording, still the revolutions and other elements must have been the same in both.

If it be admitted that there existed before Brahmagupta (Śaka 550) Siddhāntas which were either completely similar or similar in respect of the numbers of revolutions and other elements to the Soma, Romaśa and Vasiṣṭha etc. how can it be said that the modern Sūrya Siddhānta, which resembles these three in respect of elements and which is commanding a greater reverence and importance at present than these three could not have existed before Brahmagupta's time ? The modern Sūrya Siddhānta or the Soma, Romaka and Vasiṣṭha, have no similarity with respect to elements with the first Ārya Siddhānta, which existed before Brahmagupta, and with any of the earlier five Siddhāntas of the Pañcasiddhāntikā. It has already been shown above that Lāṭācārya had compiled a work quite independently ; and according to Brahmagupta's remarks, the figures for the mean places* of all planets in Śrīṣeṇa's Romaka and Viṣṇucandra's Vasiṣṭha had been borrowed from Lāṭ 's work. It appears from this that it was only Lāṭācārya's work which was similar to modern Soma, Vasiṣṭha and Romaka, out of those, which existed before Brahmagupta's time. This fact, which emerges from the above considerations, when weighed together with Albiruṇī's statement that Sūrya Siddhānta was compiled by Lāṭa, lead one to draw the definite conclusion that, the mean places of planets i.e. and the numbers of revolutions and other elements in the modern Sūrya Siddhānta, have been taken from Lāṭācārya's works and Lāṭa lived before Varāhamihira (Śaka 427). Hence, it is the author's opinion that the elements in the modern Sūrya Siddānta belong to a period prior to Śaka 427. Even if the modern Sūrya Siddhānta is not supposed to have been compiled by Lāṭa, the modern Soma, Romaka and Vasiṣṭha Siddhāntas definitely existed before Brahmagupta's time ; and the modern Sūrya Siddhānta is much more revered and regarded as important than any of these three. This shows that the modern Sūrya Siddhānta existed before the three Siddhāntas and hence, the date of its compilation cannot be later than the 5th century of Śaka era.

Let us now consider the five Siddhāntas separately and in greater details.

*Colebrooke interprets the words as "Mars and other planets were taken from Vasiṣṭha" But considering all facts with reference to the context, I think that the lines should be interpreted in the very way in which I have rendered them.

SŪRYA SIDDHĀNTA

Subject Matter and Date

The modern Sūrya Siddhānta has 14 Chapters. All of them together contain 500 verses in 'anuṣṭup' metre. The verses at the beginning, out of those which have given the numbers of revolutions and other, elements etc. above, show that a person who was a "part of God Sun Himself" described by Sun's order, this Siddhānta to Maya, an Asura, at the end of, the Kṛtayuga. It means that 2164996 years elapsed after its *revelation*, till the beginning of Śaka 1817.

An inference has been drawn above that the modern Sūrya Siddhānta was compiled by Lāṭa and hence, it must have existed in a period much earlier than Śaka 427. It, however, seems that it had not received 'Sūrya Siddhānta' as the name at the time of Varāhamihira, because the Pañcasiddhāntikā contains only one Sūrya Siddhānta, and it is different from the modern one. A reference to the Sūrya Siddhānta has occurred at two places in Bramhagupta Siddhānta. The couplets have already been given before (See page 7). We have no reasons to say that there were two Sūrya Siddhāntas at the time of Brahmagupta, and hence, it cannot be said for certain that in his time also, the modern Sūrya Siddhānta had received 'Sūrya Siddhānta' as its name ; and even if it had, it clearly appears not to have received so much importance. Because he has taken in his work, Khaṇḍakhādyaka, elements, not from his own Siddhānta or from the first Āryasiddhānta or from the modern Sūrya Siddhānta but from the Sūrya Siddhānta of the Pañcasiddhāntikā. Hence it cannot be said for certain as to when the modern Sūrya Siddhānta received the name 'Sūrya Siddhānta or inspired a feeling of reverence.' There is, however, some room for drawing an inference.

Even if the modern Sūrya Siddhānta were compiled by Lāṭa, it is not probable that all the verses in it were compiled by him. Some or almost all the remaining verses in it, except those mentioning the elements in the chapter on mean places, might have been taken from the original Sūrya Siddhānta, that is, the one belonging to the Pañcasiddhāntikā group. Otherwise, if the Lāṭa's work be not in the same form, as the present Sūrya Siddhānta, some one else must have compiled the modern Sūrya Siddhānta, by borrowing number of revolutions and other elements from Lāṭa's work and the remaining verses from the original (ancient) Sūrya Siddhānta soon after the Pañcasiddhāntikā, and two or three centuries later, it must have been an object of reverence, when the traces of its authorship were lost and forgotten.

Brahmagupta remarks (see page 8) that the Romaka and Vasiṣṭha Siddhāntas were compiled by adopting Āryabhaṭa's method of geocentric calculations of planets ; but the main elements of degrees of epicycles (paridhyaṃśa) which are so necessary for the geocentric calculations as given by Sūrya, Romaka, and others, do not agree with those of Āryabhaṭa but with the original Sūrya Siddhānta in many respects. (See the elements given in the first chapter on 'true places' later on).

The inference which follows is that either Lāṭa or whosover be the author of the Sūrya Siddhānta, he adopted only, different numbers for revolutions and other elements etc. but borrowed the remaining items from the original Sūrya Siddhānta or retained them, word for word, as given in the original Sūrya

Siddhānta. Similarly, Brahmagupta clearly says that the elements given by Śrīṣeṇa's Romaka and those in Viṣṇucandra's Vasiṣṭha belong to Lāṭa himself. It seems that some one afterwards adjusted these Siddhānta with the original Sūrya Siddhānta in respect of principles, by omitting the remaining items which were taken from the first Āryabhaṭasiddhānta. Utpala has in his commentary on the 18th chapter of Bṛhatsaṃhitā given the following verse, preceded by "tathācācāryaḥ Viṣṇucandraḥ", meaning "so says the Ācārya Viṣṇucandra :—

दिवसकरेणास्तमय: समागम: शीतरश्मिसहितानां ॥ कुसुतादीनां युद्धं निगद्यतेऽयोऽस्त्ययुक्तानां ॥

"When Mars or any other planet along with the moon, are conjoined with the Sun in a (heliacally) set condition, it is described as a fight, even when the planets are united together."

This is in *Ārya metre*, and both the versions of Vasiṣṭha Siddhāntas are in *anuṣṭup metre*. This also leads one to infer that some one must possibly have compiled the present Vasiṣṭha siddhānta on the basis of Viṣṇucandra's Vasiṣṭha Siddhānta. The same is possible about the Romaka also.

Maya

There are some annotated versions of the Sūrya Siddhānta in the Ānandāśrama, Poona, some versions contain only the text. Here the author came to know that the 7th verse in the first chapter (on mean places) in one of the books (No. 2909) without a commentary, is not found in the annotated version It stands thus together with the foregoing and following verses :

न मे तेज: सह: कश्चिदाख्यातुं नास्ति मे क्षण: ॥ मदंशपुरुषोयं ते नि:शेषं कथयिष्यति ॥ ६ ॥

तस्मात् त्वं स्वां पुरीं गच्छ तत्र ज्ञानं ददामि ते । रोमके नगरे ब्रह्मशापाल्लेच्छावतारधृक् ॥ ७ ॥

इत्युक्त्वांतर्दधे देव:

(Oh Maya !) you will not be able to bear my lustre (and) I have no time to tell you (anything of the Science). This man, who is my own part, will tell you everything. Therefore, go back to your town. I will be born as a Greek (yavana) because of Brahmā's curse, in the city of Romaka. There I will initiate you in the Science. So saying God Sun vanished from sight.

This verse stands as the verse intermediate between the 6th and 7th verses in the annotated version. The 7th verse when looked taken in the light of its context appears to be altogether disconnected. This verse was found in the two versions of the Sūrya Siddhānta without a commentary and in the possession of the Rev. E. Burgess, *translator of the Sūrya Siddhānta*, but was not found in the annotated version. Whitney in his notes on the translation, has expressed his views regarding this verse as follows :—

Although it is true that this verse is clearly out of place here, between the 5th and 7th verses of the present edition, still it is found in several manuscripts of Sūrya Siddhānta and it is not probable that it has been purposely deviced and introduced. Hence, the first seven or eight verses at the beginning which are found in the present annotated edition, must have been newly inserted by some person to describe how Maya got the Sūrya Siddhānta. Originally, only the above quoted verse along with similar others, must have occupied that place ; and it shows that the Sūrya Siddhānta must have undoubtedly some connection with the Greeks in some way or the other ; not only this but the Science must have been obtained by the Hindus from the Greeks. Even

the modern Sūryasiddhānta states that the 'Sūrya Siddhānta was revealed to Mayāsura'. What was the propriety in selecting a demon (an 'asura') as the medium of revelation by the Sun ? This point also indicates an association with the Greeks.

Ptolemy

Weber says that according to Hindu inscriptions Turumaya was the name of king Ptolemaios' of Egypt. From this Asuramaya appears to have been a corruption of Turumaya, and Maya seems to be the Ptolemy* himself who was the author of the Almajest. But it has already been pointed out that Ptolemy's work has no connection with the original Sūrya Siddhānta. Similarly, the numbers of revolutions and other elements of the modern Sūrya Siddhānta given above do not at all tally with those of Ptolemy. This clearly shows that Ptolemy has absolutely no connection with the modern Sūrya Siddhānta.

A Relation between the two Sūrya Siddhāntas

Utpala's commentary on the Bṛhatsaṃhitā quotes the following verses as belonging to the Sūrya Siddhānta :—

महतश्चाप्यध:स्वस्य नित्यं भासयते रवि: ।। अर्धं शशांकबिंबस्य न द्वितीयं कथंचन ।।

तेजसां गोलक: सूर्यो ग्रहक्षण्यंबुगोलका: ।। प्रभावंतो हि दृश्यंते सूर्यरश्मिविदीपिता: ।।

विप्रकर्षं यथा याति ह्यधस्थश्चंद्रमा रव: ।। तथा तस्य च भूदृश्यमंशं भासयते रवि: ।।

अध्याय ४ चंद्रचार

भूछायां शशिकक्षागां रवौ भावां (?) तरस्थिते ।। यदा विशल्यविक्षिप्तश्चंद्र: स्यात्तद्ग्रहस्तदा ।।

इंदुना छादितं सूर्यमधोविक्षिप्तगामिना ।। न पश्यंति यदा लोके तदा स्याद्भास्करग्रह: ।।

तमोमयस्य तमसो रविरश्मिपलायिन: ।। भूछाया चंद्रबिंबस्थोर्द्धं परिकल्पित: ।।

अध्याय ५ राहुचार,

"The sun illuminates half the disc (side) of the moon, even if it is occupying the lowest position (with respect to the sun) ; and the second half is never illuminated.

The sun is a sphere of lustre. The planets, the stars and particles of water shine brightly when they are illuminated by the sun.

The farther the moon goes away from the sun, while in a lower position, the greater portion of its disc becomes visible to (people on) the earth."

—*Chapter 4 on Moon's motion*

"While the sun is situated in the house opposite to that of the moon, and when the moon, having no latitude, enters that portion of the earth's shadow which intercepts the moon's orbit, the lunar eclipse takes place.

*See page 3, Translation of the Sūrya Siddhānta by Burgess. The statement of Weber has not been given above word by word, but only its summarized form.

When the sun's surface is obstructed by the moon who is passing in a downward direction and when people on the earth are unable to see the sun, then the solar eclipse takes place.

The *earth's shadow which is cast by the sun's rays, falls only on one half (Portion) of the moon's disc which is escaping from the darkness cast by Rāhu.

—Chapter 5 on Rāhu's motion.

These verses are not found in the modern Sūrya Siddhānta. It is not therefore, certain if they at all belonged to the original Sūrya-Siddhānta. If they did, it may be said that the modern Sūrya Siddhānta was not held in great reverence at the time of Bhatotpala (Śaka. 888).

Bhatotpala, in the course of his discussion of Mahākārtikādi Saṃvatsara, in the chapter on gurucāra, in the commentary on Bṛhatsaṃhitā, observes.

केचित्कृत्तिकादियुक्ते गुरौ यच्चंद्रयुक्तं नक्षत्रं चैत्रमासादितो भवति ततो महाकार्तिकादीनि

संवत्सराणि प्रभवादीनि च गणयंति ।।

"Some (astronomers) when they find that Jupiter has come to the star Kṛtikā, and Caitra has started, reckon the beginning of the cycle of Mahākārtikādi years and also that of the prabhava year, on the basis of the star with which they find the moon to be conjoined."

The method of naming the years of the Mahākārtikādi Series, as given in the modern Sūryasiddhānta, is as follows :—

वैशाखादिषु कृष्णे च योगः पंचदशे तिथौ ।। कार्तिकादीनि वर्षाणि गुरोरस्तोदयात् रथा ।। १७ ।।

मानाध्याय.

In Vaiśākha etc., a conjunction (yoga) in the dark half-month (kvṣṇa on the 15th lunnar day (tithi) determines, in like manner, the years Kārtika etc of Jupiter, from its heliacal setting (asta) and rising (udaya).

Chapter on Elements.

These two have much similarity and this method of naming the Māhakārtikādi years is found in no work other than the Sūrya Siddhānta. It cannot be kown from the Pañcasiddhāntikā if this method was given in the original Sūya Siddhānta and there is no other way to find it. If Bhaṭotpala's quotation refers to the original Sūrya Siddhānta, it would be a good means to prove that the verses from the original Surya Siddhanta occur also in the modern Sūrya Siddhānta.

Lāṭa

Albiruṇī, (Śaka 952 circa) says that the Sūrya Siddhānta was compiled by Lāṭa. But the original Sūrya Siddhānta in Pañcasiddhāntikā was undoutedly not compiled by Lāṭa, for had it been so, Varāha would have mentioned it and

*Different readings are found in different works and the author himself is doubtful about the words "bimbasthordhe". We come across bimbasyasthanerdhe, bimbasyordhwe etc. I have attempted to give the likey meaning—Translator.

would not have included it in the Pañcasiddhāntikā. According to Brahmagupta, the work by Lāṭa is clearly different from the Sūrya Siddhānta. He has, in addition, criticised Lāṭa's work in two or three places, but not the Sūrya Siddhānta. This shows that the Sūrya Siddhānta referred to by Albirunī as compiled by Lāṭa is not the original Sūrya Siddhānta but the modern one, and from this it appears that the importance of the Sūrya Siddhānta had been established before Śaka 952.

The author of Bhāsvatikaraṇa declares at the outset of his work :—

अथ प्रवक्ष्ये मिहिरोपदेशात् । तत्सूर्यसिद्धांतसमं समासात् ॥ ३ ॥

अधिकार २

"As instructed by Varāhamihira, I briefly compile this (Karaṇa) work which is similar to his Sūrya Siddhānta".

The words, "tatsūryasiddhānta" in this, show that there existed at the time of the author of 'Bhāswatī', a Sūrya Siddhānta different from the one incorporated by Varāhamihira in his work.

The following verses from the Sūrya Siddhānta have been given by Bhāskarācārya himself in his commentary, *vāsanā*, on Siddhānta Śiromaṇi :—

अदृश्यरूपाः कालस्य मूर्तयो भगणाश्रिताः ॥ शीघ्रमंदोच्चपाताख्या ग्रहाणां गतिहेतवः ॥ १ ॥

तद्वातरश्मिभिर्बद्धास्तैः सव्येतरपाणिभिः ॥ प्राक्पश्चादपकृष्यंते यथासन्नं स्वदिङ्मुखं ॥ २ ॥

"(1) Forms of Time of invisible shape, stationed in the *Zodiac* called the conjunction (śighrocca), apsis (mandocca) and node (pāta) are causes of the motion of the planets."

"(2) The planets, attached to these beings by cords of air, are drawn away by them, with the right and left hand, forward or backward, according to nearness, towards their own places."

These verses are given by the modern Sūrya Siddhānta (see verses 1 and 2 in the chapter on 'true place'). Similarly, Bhāskarācārya, in the chapter on *Golabandha*, remarks about the motion of the equinox as follows :—

विषुवत्क्रांतिवलययोः संपातः क्रांतिपातः स्यात् ॥

तद्भगणाः सौरोक्ता व्यस्ता अयुतत्रयं कल्पे ॥ १७ ॥

"The point of intersection of the Equator and the Ecliptic, is called '*Krāntipāta*'. The number of its revolutions in one kalpa, according to the Sūrya Siddhānta is 30000" and in his commentary of this verse, he himself says,

क्रांतिपातस्य भगणाः कल्पेऽयुतत्रयं तावत् सूर्यसिद्धांतोक्ताः ॥

Sūrya Siddhānta itself has cited 30000 as the number of revolutions of the krāntipāta in one kalpa.

This remark refers to the revolution of the zodiac mentioned in the modern Sūrya Siddhānta. Similarly the word '*arkāṃśa*' occuring in Bhāskarācārya's remark* "tasmānnedaṃ pūrvairarkāṃśādyaistathā kṛtaṃ karma" at the end of the chapter on 'solar eclipse', seems to refer to the modern Sūrya Siddhānta.

*Meaning—This calculation has not been made by former astronomers like Arkāmśa (Incarnation of the Sun).

When held in reverence

These arguments prove that the modern Sūrya Siddhānta had achieved the position of authority and reverence before the times of Albiruṇī, Bhāsvatīkāra and Bhāskarācārya i.e. before the first half of the 10th century of Śaka era. There is no evidence available at present to show what time it was between the Śaka 550 (i.e. the time of Brahmagupta's Siddhānta) and Śaka 950.

WORKS FOLLOWING MODERN SŪRYA SIDDHĀNTA

The *Karaṇa work* written in Śaka 1220 by Vavilala Kochana of Tailangana completely follows the modern Sūrya Siddhānta. It has not found any Karaṇa work written on the lines of the modern Sūrya Siddhānta prior to this date. The Bhaṭatulyakaraṇa, written in Śaka 1339 gives the same motion for the equinoxes as that given by the modern Sūrya Siddhānta. A work called *Tājakasāra*, written in or about Śaka 1445, has come to the notice. While describing the method of calculating the planets' places, it writes;

श्रीसूर्यतुल्यात्करणोत्तमाद्वा स्पष्टा ग्रहा राजमृगांकतो वा ॥

"The true places of planets can be calculated either by the method given by Śrisūryatulya-Karaṇa work or by the one compiled by Rājamṛgāṅka."

It shows that there existed before Śaka 1445, a Karaṇa work named *Sūrya-tulya*. The places of planets in it were, of course, taken from the Sūrya Siddhānta and they must have been from the modern one itself. The figures for the length of the year etc. cited by 'Grahakautukakaraṇa' in Śaka 1418 as having been taken from Sūrya Siddhānta belong to the modern Sūrya Siddhānta. Ganeśa Daivajña, the author of Grahalāghava, says

सौरोऽर्कोऽपि विधूच्चमंककलिकोनाब्जः ॥

ग्र० ला० मध्यमाधिकार०

Meaning :—The elements for the sun, the moon's apogee and that for the moon diminished by 9′ have been borrowed from the Sūrya Siddhānta.

And these elements have been definitely taken from the modern Sūrya-Siddhānta. Similarly, *the tables of Tithi Cintāmaṇi* have been prepared completely from the positions of the Sun and other planets as given by the modern Sūrya-Siddhānta. (More discussion about this will appear later in the course of the comments on Grahalāghava). A commentary on Bhāswatīkaraṇa was written by Mādhava in Śaka 1442, *i.e.* in the same year in which the Grahalāghava was compiled. This commentary includes the verses, giving the revolutions of the sun, the moon, and all planets or the figures indicated in those verses. These verses and the numbers of revolutions and other elements, except those for Rāhu, completely agree with those of the modern Sūrya Siddhānta.

Makaranda is the name of a work helpful in preparing the almanac Almanacs are compiled from it in many parts of Northern India at present. The measure of the year and the numbers of revolutions and other elements for all planets have been taken by it from the modern Sūrya Siddhānta. The date of its compilation as given in the version of the Makaranda work, printed at Vārāṇasi, is Śaka 1400. This Śaka number has not been stated in verse

form and no other means is available in the work to prove that it is true, which leaves some room for doubt about its authenticity. Makaranda is, however, referred to by Viśvanātha and others which shows that the date may be correct. Paramādīśvara, the commentator on the Āryabhaṭiya has given 12 verses* from different chapters in the modern Sūrya Siddhānta and four of them, which are specially important, belong to the chapter on mean places, and they mention revolutions of the aphelia and nodes of all planets. The date of this Paramādīśvara is not known. The verses quoted by him from Sūrya Siddhānta are every where, preceded by the words "tathā ca Mayaḥ" meaning "so says Maya".

The work, *Tājikabhūṣaṇa*, was written about Śaka 1480, by Ganeśa Daivajña, son of Ḍhunḍhirāja and resident of Pārthapur (Pathāri) near river Godāvari. He has adopted in it the length of the year as given by the original S. S. The measure for the year (viz. 365d—15gh-31p-30v) as adopted by the original Sūrya Siddhānta appears to have been in continued use till the end of the 15th century, because it was more convenient for calculation than the one (365d—15gh-31p-31v-24pv) adopted by the modern Sūrya Siddhānta.

There is a work on Muhūrta, named *Jyotiṣadarpaṇa*, which was compiled in Śaka 1479. It casually gives as an example, the ahargaṇa (*i.e.* number of days elapsed) from the beginning of creation to the beginning of Kaliyuga. Similarly, the mean places of planets for the midnight of Thursday in the beginning of Kalpa have been given in it, and they are all similar to those of modern Sūrya Siddhānta.

There is a Karaṇa-work, *Rāmavinoda* by name, compiled in Śaka 1512, which gives the length of the year according to modern Sūrya Siddhānta. Kamalākara, 1580, the author of the '*Siddhānta tatvaviveka*' is a staunch admirer of the modern Sūrya Siddhānta. The work *Vārṣikatantra*, which follows the modern Sūrya Siddhānta was written sometime between Śaka 1400 and 1634.

Commentaries

A commentary on the modern Sūrya Siddhānta entitled 'Gūḍhārthaprakāśikā' by Raṅganātha was written in Śaka 1525. An edition of Sūrya Siddhānta together with this commentary, has been printed at Vārānasi and Calcutta. A second commentary, entitled Saurabhāṣya was written by Nṛsiṃha Daivajña and belongs to Śaka 1542. A third commentary was written by Viśvanātha Daivajña and entitled 'Gahanārthaprakāśikā'. It contains examples with solutions and belongs to about Śaka 1550. A fourth commentary, written by Dādābhāī and entitled 'Kiraṇāvalī' was written in Śaka 1641. Of these four commentaries, that by Raṅganātha is more exhaustive and contains a good explanation of the theoretical aspect. Raṅganātha's commentary contains at 2 or 3 places the remark** "इति सांप्रदायिकं व्याख्यानं" meaning "this is according to tradition", and he has endorsed the views of others at 2 or 3 places with the remark† केचित् meaning "according to some". At one place is found the statement "नव्यास्तु इत्थं कुर्वंति" meaning "modern†† people interpret it thus". This shows that some commentaries belonging to an earlier period were available in Raṅganātha's time. Raṅganātha has mentioned at four places, Parvata, as the name of some commentator, and has given a half-verse‡

*See verses 41 to 44 from Madhyamādhikāra ; No. 2 from Pātādhikāra, Nos. 35 to 40 from Bhūgolādhyāya and one from Mānādhikāra.

**See pages 156, 163, 201 of the Vārānasī edition.

†See pages 48, 95, 147, Vārānasi edition.

††See Vārānasī edition page 201.

‡See Varanasī edition page 212.

characterized as "नार्मदोक्त" (quoted from Nārmadā). It shows that there must have existed some mathematical work of Nārmadā in which some reference to or a corroborative statement of modern Sūrya Siddhānta could be found. In my opinion* the date of this Nārmadā must have been about Śaka 1300. Colebrooke says that there is a commentary on the Sūrya Siddhānta by Bhūdhara. Similarly, Prof. Whitney† remarks, on the basis of Wilson's catalogue, that commentaries on the whole or part of that work by Mallikārjuna, Yellayā, Āryabhaṭa, Mammabhaṭa and Tammayā, were available in the Mackenzie's Collections. A commentary by any of the two Āryabhaṭas on any of the two Siddhāntas seems to be an impossibility. Hence, there appears to be a commentary by some third Āryabhaṭa.

Bibliotheca Indica includes an English translation of the Sūrya-Siddhānta made in 1860 A. D. by Pandit Bāpūdeva Śāstrī (New series No. 1). It contains simply the translation of the text and some notes here and there. The English translation of the Sūrya Siddhānta by the Rev. Ebenezer Burgess was published by the American Oriental Society as volume VI of its Journal in 1860 ; and it has been printed in a separate volume. It was Burgess who first translated the work and added foot notes to it and Prof Whitney further added extensive notes on it. Prof. Whitney has admitted his responsibility about the views etc. expressed in these notes. It is the opinion of Prof. Whitney†† that the Hindus borrowed astronomy from the Greeks. According to Burgess on the other hand it was the Greeks who borrowed astronomy from the Hindus and this view has been expressed by him at the end of the volume.

Interpolation

Raṅganātha after giving a half-couplet in his note on the 23rd verse from the Chapter on 'conjunction of planets', has remarked that he has not commented upon the verse, since, it is found only in some works and not in all and appears to be interpolated. Similarly, after passing over 1½ couplet in the Chapter on 'elevation of moon's cusps' he has given his commentary in the next two verses and has remarked "but these appear to be disconnected and the method described therein is erroneous, they might have been interpolated by some very intelligent person who depended upon the "*Dhīvṛddhidatantra of Lalla*". He has also remarked that the four verses beginning from the 5th in the *Tripraśnādhikāra* might be regarded by some as interpolated, but it is not so ; this shows that there were in his time some persons or commentators who regarded these verses as interpolated. *Jyotiṣadarpaṇa*, a work on Muhūrta, contains about 19 verses from the chapters on mean places and on elements from the modern Sūrya Siddhānta which tally with those in the modern versions of the Sūrya Siddhānta ; but there are 3 more verses, not given in the commentary by Raṅganātha and inserted between some preceding and following verses from the original, and these do not appear contradictory to the context.

Diffusion

Out of the authors of *Karaṇa and other works* which have adopted the numbers of revolutions and other elements from the Sūrya Siddhānta and out of the commentators thereon described above, the author of the Grahalāghava and Keśava, his father, belong to Koṅkaṇa and Mādhava, the commentator of *Bhāsvatīkaraṇa* hails from Kānyakubja, that is, Kanauj. The

*See the description of Nāramadā, later on in this very chapter.

†See Translation of the Sūrya Siddhānta by Burgess, page 278.

††Prof. Whitney died in 1894.

in a particular period of time and their mean position at a particular moment ; and *The third* is their true motions and true positions, by which is to be understood their position which is actually observed in the heavens, as being somewhat different from their position calculated from their mean motions, and the causes of this difference, the elements for finding out this difference at a particular time and the method of finding it ; all problems (in astronomy) can thus be said to be included in these three types. That branch of astronomy which is known in English as Physical astronomy, is in the author's opinion to belong to the first type of the 'formation of the Universe.' The knowledge of astronomy concerning the second and third types, and specially the third, gradually developes with the growth of this (first) type. There is, however, no harm if it be said that no discoveries were made in our country, comparable with the several important discoveries that were made in the European astronomy after Copernicus. Hence, it can be said that the history of 'the formation of the Universe' does not hold an important position in the Hindu astronomy as it does in the European astronomy. All works have propounded almost the same views and no further discoveries have been made in them. It will, therefore, be better to describe all problems of the first type in one place. Some of them have been mentioned in the Introduction, and others will be treated later on. The problems belonging to the second type, being different for different Siddhāntas, have been described separately at their proper places ; and some topics belonging to the third type will be given later in the study of the Universe, and the remaining in the chapter on true places ; and these problems being the same in the case of each Siddhānta, it is better to mention them in one place in the chapter on true places. It will also be advantageous to indicate the differences between the Siddhāntas by comparison and this plan, when followed, will cover the study of all problems in the Siddhāntas.

The numbers of revolutions and other elements etc. in the Siddhāntas of the Pañcasiddhāntikā and in the five Siddhāntas of this chapter, have already been mentioned above. The mean positions of planets given in the Siddhāntas of the Pañcasiddhāntikā have also been compared with those calculated from European works.

A comparison of mean planets given by the modern five Siddhāntas, including the Sūrya Siddhānta, with those calculated from the European works will be made in the description of Āryabhaṭa later on.

SOMA SIDDHĀNTA

The Date

This Siddhānta has been described by Candra to the sage Śaunaka. It mentions the number of years elapsed from creation up to the beginning of the present Kaliyuga and directs us to "add the desired number of years elapsed from the present Kaliyuga". This proves that this Siddhānta has been compiled in the Kaliyuga. The real date of its compilation is the same as that established for the modern Sūrya Siddhānta or one somewhat later than it.

It has 10 chapters and 335 verses in 'anuṣṭup' metre.

A work, entitled *Jyotiṣa Darpaṇa*, mentioned above, gives a verse from the Soma Siddhānta. The Raṅganātha's commentary on the Sūrya Siddhānta gives at one place a verse from this (*viz.* Soma Siddhānta). Kamalākara, the author

of the Siddhāntatatvaviveka, has referred to the Soma Siddhānta in the following verse :—

ब्रह्मा प्राह च नारदाय हिमगुर्यच्छौनकायामलं ।।
मांडव्याय वसिष्ठसंज्ञकमुनिः सूर्यो मयायाह यत् ।। ६५ ।।

भगणमानाध्याय.

"(65) That pure (science of astronomy) which was revealed to Maya by the god Sun, was described to Nārada by Brahmā, to Śaunaka by Himaguru (Moon or Soma) and to Māṇḍavya by the sage Vasiṣṭha."

—Chapter on elements of revolutions.

The Chapter on mean places in this Siddhānta gives the following two couplets as "verses quoted from Gārga".

अथ, माहेश्वरायुष्ये...ब्रह्मणोधुना ।। सप्तमस्य मनोर्याता द्वापरांते गजाश्विनः ।। २८ ।।
खचतुष्कभनागार्थशररंध्रनिशाकराः १९५५८८०००० ।। सृष्टेरतीताः सूर्याब्दा वर्तमानात्कलेरथ ।।

"1955880000 solar years have elapsed from the creation up to the (beginning of the) present Kaliyuga, which begins from the end of the Dwāpara yuga and which is 28th (yuga) in the 7th-Manu period, belonging to the present Brahmā's day—during the life of God Śiva".

These very verses occur in Romaśa Siddhānta also, as "quoted from Garga". The former half of the first verse in this runs thus,

"परार्धप्रथमाहेस्मिन्नायुषो ब्रह्मणोधुना"

—meaning-"in the latter half of the present day of Brahmā's life."

The word Nanda occurs at one place in this Siddhānta. It has already been pointed out above that this Siddhānta resembles the Sūrya Siddhānta in all respects.

VASIṢṬHA SIDDHĀNTA

Subject Matter

It has already been pointed out above that there are two versions of Vasiṣṭha Siddhānta which are similar in principles but different only in form. Of these, the one, printed at Vārānasī, has five chapters, containing 94 verses in 'anuṣṭup' metre. It has been mentioned in the beginning and at the end that this Siddhānta was revealed by the sage Vasiṣṭha to the sage Māṇḍavya. This Siddhānta is very brief. Other Siddhāntas mention the numbers of revolutions and other elements in addition to the measures of orbital lengths also. This (siddhānta) gives only the orbital lengths and the numbers of the revolutions of planets in a Yuga have got to be calculated from them. These can be found and they agree with the Sūrya Siddhānta. This is also incomplete with respect to some other subjects. This does not mention* the number of 'sāvana' days in a yuga. It is not mentioned from what epoch the ahargaṇa

*The copy in the Deccan College Library Collection gives the number of revolutions of stars, from which the number of 'sāvana' days can be found; but it has been pointed out (page 29) that they prove to be different (from those in the Sūrya Siddhānta).

is to be reckoned. While the use of utkramajyā (versine) has been mentioned, no lists of versines are given*. The aphelia and nodes have not at all been mentioned. The following lines are given about them :—

मंदोच्चपातभगणाननुपपत्यानयेद्युगे ॥ यत्र मंदफलं शून्यं मंदोच्चस्थानमुच्यते ॥ ३१ ॥
याम्यकेंद्रफलं शून्यं पातस्तत्रविनिर्दिशेत् ॥

मध्यमाधिकार.

"Calculate from theory the numbers of aphelia and nodes in a Yuga. The point at which the 'equation of centre' is zero, is called the 'mandocca, (aphelion); the point at which the yāmya-kendra-phala (value of celestial latitude) is zero, is called a pāta (node)."

The calculator has been asked to find out the aphelia and nodes by observation, and in a way, he has been asked to compile a new Siddhānta. It describes the method of finding a'Karṇa', but it is incomplete. It has five 'adhikāras' (chapters) which deal with only the following subjects :—(i) mean places (ii) true places (iii) Shadow (three problems) (iv) miscellaneous and (v) geography. The miscellaneous chapter gives just a glimpse into the eclipses. Even the chapter on 'shadow' is very brief. A verse in the chapter on true places is given from the modern Sūrya Siddhānta. Regarding the ahargaṇa, it has been remarked that it is true for the midnight at Laṅkā ; this also proves its similarity with the Sūrya Siddhānta. The words Rāma, Nanda, and Siddha have been available in it.

DIFFERENT VERSIONS

Raṅganātha has taken a half-couplet from this as belonging to *Laghuvasiṣṭha* Siddhānta. He has similarly given a verse regarding eclipses as "quoted by *Vṛddha Vasiṣṭha*" and at one place in his commentary on the chapter on true places he has mentioned the name of Vṛddha Vasiṣṭha. This leads me to suspect if there existed in Raṅganātha's time a different Vṛddha Vasiṣṭha Siddhānta. The verse about the eclipse quoted by him is given in 'upajāti' metre and not in 'anuṣṭupa metre. The Vasiṣṭha Siddhānta referred to by Kamalākara (page 29) appears to be the Laghu Vasiṣṭha Siddhānta.

The other version of Vasiṣṭha Siddhānta mentioned above as belonging to the Deccan College Collection, has only one chapter entitled 'madhyamādhikāra', which contains only the description of the formation of the Universe and orbital lengths of planets, and does not give other chapters generally found in other Siddhāntas. All verses are in anuṣṭup metre. The remark at the end runs "in Viśvaprakāśa, from the Gaṇita branch, compiled by Vṛddha Vasiṣṭha" followed by the words "the 4th chapter on orbits". There is no hint or clue for finding where the remaining three chapters ended. This shows that the work remained incomplete. The references at the beginning show that this Siddhānta was revealed by Vasiṣṭha to Vāmadeva, and Māṇḍavya has not been mentioned.

ROMAŚA SIDDHĀNTA

This Siddhānta has been described by Viṣṇu to Vasiṣṭha and Romaśa. The verses concerning this have already been given before (page 34).

*These can be calculated from the kramajyās which are given in it.

It has 11 Chapters, consisting of 374 verses in anuṣṭup metre. It has already been mentioned that it completely resembles the Sūrya Siddhānta as regards the numbers of revolutions and other elements etc.

Any reference to verses from this Siddhānta in any other work could not be detected.

The words Nanda, and Siddha have occurred in this. The word Āra meaning Mars, has occurred once. The names of rivers have been given which included 'Kṛṣṇā veṇī.' This suggests that the author of this work might be some person from South India.

BRAHMASIDDHĀNTA CITED BY ŚĀKALYA

Author

This has 6 chapters and 764 verses. This was described by God Brahmā to Nārada. The original verses nowhere mention Śākalya's name, but each chapter ends with the phrase "in the second problem (praśna) of the Brahmasaṃhitā in Śākalya Siddhānta". Among the— 'problems' of Śākalyasaṃhitā there is not a single one which we meet at present. A number of lines have been taken in Raṅganātha's commentary on different occasions, and while giving them, the phrase "from Śākalya" is added at some places, and the phrase in Brahmasiddhānta at others. The verse in which the author of the Siddhāntatatvaviveka has referred to this Siddhānta is already mentioned (page...47...). Kamalākara has taken even some verses from this Siddhānta.

The numbers of revolutions and other elements in this tally entirely with those of the Sūrya Siddhānta in all respects and have already been given.

Subject Matter

It has not, like other Siddhāntas, separate chapters, such as a chapter on mean places, a chapter on true places, etc. Each chapter contains a subject pertaining to some 'adhikāras' and the six chapters together cover almost all the subjects usually given in a Siddhānta ; not only this, but the subject of religion also, which is never met with in an astronomical work, has been included in it. The third chapter deals with the study of Mahāpāta (parallel of declination) of the sun and the moon ; and after mentioning the 'fruits' of bath and charity undertaken on these auspicious occasions, the subject of religion has been introduced as an offshoot of the main subject and it covers the portion between the 34th verse and the end of the chapter. Thus, as many as 138 verses have been devoted to this subject which includes the follow ing items :—the holy time for Saṃkrānti ; the end of a tithi-gaṇḍa ; the consideration as to when to accept a tithi covering the 'pradoṣa' time, and when that 'enveloping' the noon time or that which comes in contact with the former tithi etc.; similarly, the decision of the proper time for Ekādaśi Śrāddha, Yāga (*i.e.* sacrifice) and of special rites like the Upākarma and o special tithis, like the Ganeśa Caturthī.

Date

The first chapter deals with the question who created the science of astronomy and contains the following verse,

एतच्च मत्तः शीतांशोः पुलस्त्याच्च विवस्वतः ।। रोमकाच्च वसिष्ठाच्च गर्गादपि बृहस्पतेः ।। ६
अष्टधा निर्गतं शास्त्रं ... ...

"This (science) has been created (compiled) in eight ways, viz. by me, by Soma, Pulastya, Vivasvān (sūrya), Romaka, Vasiṣṭha, Garga and Bṛhaspati".

The word *mattah* in this refers to this Siddhānta. Garga and Bṛhaspati have got only Saṃhitās to their credit, while Siddhāntas bearing the names of Soma, Pulastya, Sūrya, Romaka and Vasiṣṭha are well known. The Pulastya's Siddhānta is the same as Pauliśa Siddhānta. It is referred to even by the name 'Pauliśa' in this Siddhānta at two or three places. The following line occurs once in the first chapter:—

तस्मात् पंचसु सिद्धांतेषूक्तमार्गोविचार्यतां ॥ ६० ॥

"Hence the desired method should be followed as given by one of the five Siddhāntas."

The names, Sūrya, Soma, Romaśa and Puliśa, have also occurred at two or three other places. This clearly shows that this (Brahma) Siddhānta was compliled after all the above Siddhāntas. It is very difficult to say in what particular period of time it was compiled ; but the first chapter in this contains the line,

प्रमाथिप्रथमं वर्षं सौरं कल्पस्य सर्वदा ॥ ३७ ॥

"The name of first year of Kalpa is Pramāthi by solar measure."

Most of the works follow the method of reckoning the Prabhāva and other years of the 60-year cycle on the basis of Jupiter's motion. It is only this Siddhānta, the Romaśa Siddhānta and the commentary by Bhaṭotpala which refer to the adoption of the system, (of naming the year) by solar measure ; and it is only in this Siddhānta, that according to solar measure, the name of the first year of Kalpa is Pramāthi, and it will be found that the desired 'samvatsara' is always obtained on this basis by adding 12 to the Śaka year (in question). At present, the samvatsara is not named by Bārhaspatya system, south of Narmadā, but by solar measure and thus we get the desired samvatsara by adding 12 to the Śaka. But one year is suppressed in about 85 years if the Jovian measure is followed. Hence, we do not get the correct Jovian year by adding the same number to the Śaka year every time. The figure to be added was shorter than 12 before Śaka 743. The correct Jovian year used to be obtained by adding 12 between the period Śaka 743 and 827. This figure is to be increased by one, after every 85 years. Copper plates and other inscriptions show that the system of finding a Bārhaspatya (Jupiter's) samvatsara was the same in South India as in the North India till Śaka 743 ; but the number 12 was required to be added between Śaka 743 and 827. The author is of opinion that the system of reckoning a year by solar measure must have been adopted in South India from that period. A detailed consideration of this point will be made later on in the study of *samvatsara*. Because, this Siddhānta contains the method of finding a samvatsara by adding 12 to the current Śaka, and states the first year of Kalpa to be Pramāthi, there is no doubt that this Siddhānta must have been compiled some time after Śaka 743 and not before.

It is the speciality of this work that it gives the latitudes and longitudes of the stars in Saptarṣi group (*i.e.* Great Bear), which are not given by any other siddhānta.

FIRST ĀRYABHAṬA

Name

He has compiled the well known work *Āryabhaṭīya.* There is no other more ancient work from amongst the available 'pauruṣa' (human) astronomical works. He calls his work as Āryabhaṭīya, but many other astronomers have named it as Āryasiddhānta and it is quite proper to name it thus. A second Āryabhaṭa flourished after him and he has also written an Āryasiddhānta. It is, therefore, convenient to mention this Āryabhaṭa as Āryabhaṭa I, and his work as the First Āryasiddhānta, and the author has followed this principle all throughout.*

This Siddhānta is divided into two main parts. The first part consists of 10 verses in the 'gīti' metre ; and almost all the topics mentioned in the Madhyamādhikāra of other Siddhāntas ; for instance, the elements of revolutions etc. in a particular period of time, have been mentioned in these 10 'gītis'. This part is called the 'daśagītika'.

The second part has three chapters, which contain the remaining questions mentioned in the other Siddhāntas. It contains 108 āryās and hence, it is called the 'āryāṣṭāśata'. Some people regard the two parts as separate works. *Sūryayajvana,* one of the commentators of this work, calls the two parts as two 'prabandhas' (compositions). Each of the two parts begins with a verse which is an auspicious prayer and hence, they might have been regarded by some as two separate works. But they are interdependent and one will be of no use without the other. It is, therefore, proper to regard the two together as one work. Āryabhaṭa himself appears to hold the same view. He has not given any separate name for the first part, nor has he closed it by a conclusion. He has no doubt added a 'conclusion' at the end of the whole work together and has mentioned *Āryabhaṭīya* as the name only at that place. Similarly, the whole work together has four chapters; the author himself does not call them as 'pādas', still it has been customary with others to call them so. If the 'Daśagītika' be supposed to be a separate work, it will be said to have one 'pāda' and the other work three and these cannot justly be called 'pādas' (fourth parts). Considering, therefore, from all points of view, it will be proper to regard the 'Daśagītika and Āryāṣṭāśata' together as one Siddhānta. The Daśagītika contains two more 'gītis' in addition to the Ten ; one of them is the auspicious prayer and the second describes his numerical code. The whole work, therefore, contains 120 verses. The word 'Āryāṣṭāśata' is misleading, and it seems that because of this, some European scholars thought that it contained 800 verses. This Āryasiddhānta, along with the *Bhaṭadīpikā* commentary by Paramādīśvara has been recently printed by Dr. Kern at Leden in Holland in 1874. It was not much known to European scholars before this.

Three Schools

The astronomical works in our country are at present believed to belong to one of the three main pakṣas or schools ; the Saurapakṣa, the Āryapakṣa and the Brahmapakṣa. The basic work for the first school is the Sūrya Siddhānta, that for the second is the Ārya Siddhānta, and that for the third is the Brahma Siddhānta. The reason for the formation of the three different schools is that the length of the year according to each school is somewhat

*If any reference without the epithet 'first or second' occurs anywhere later on, it should be taken to refer to this, (tha (is) the first Āryabhaṭa.

different and the motions of planets in a particular period of time, say, a Kalpa or a Mahāyuga, are different. The remaining subjects in the case of all schools of all works following each of these schools are practically the same. It will be shown at the proper place when the party spirit relating to different schools raised its head.

The words Āryasiddhānta and Āryapakṣa are well known in our country but the Āryasiddhānta itself is not much known to anyone. It is considered that no orthodox astronomer in Mahārāṣṭra possesses its copy. The Āryapakṣa (school) is still flourishing and it has a number of followers ; but very few of them understand its correct form from the original Āryasiddhānta.

Numerical Code

Other astronomical works are found to be using 'bhū' for 1, 'rāma' for 3, and such other words to represent digits and numbers. But the First Āryabhaṭa, instead of following this system has adopted letters to denote numbers, as shown below :—

a—1	ḷ—100000000
i—100	e—10000000000
u—10000	o—1000000000000
ṛ—1000000	au—100000000000000

Ka— 1	Ca— 6	ṭa—11	ta—16	pa—21	ya—30	ṣa —80
kha— 2	cha— 7	ṭha—12	tha—17	pha—22	ra—40	sa —90
ga— 3	ja— 8	ḍa—13	da—18	ba—23	la—50	ha —100
gha— 4	jha— 9	ḍha—14	dha—19	bha—24	va—60	
ṅa— 5	ña—10	ṇa—15	na—20	ma—25	śa—70	

Varāhamihira has followed in the Pañcasiddhāntikā the system adopted by other Siddhāntas while using words to denote numbers; and this shows that the system was in vogue before Āryabhaṭa ; and it must have been so. Hence, Āryabhaṭa must have adopted it to represent numbers briefly and as it is not found in other works, it appears to have originated with him. This system ensures brevity. Other Siddhāntas generally require about 9 or 10 verses to mention the number of revolutions of all the planets. But it has been done only in two couplets by this system. Similarly, other Siddhāntas generally require 50 to 70 verses to be devoted to 'Madhyamādhikāra'. This system could describe almost all the subjects in 10 verses (gītis) only ; and hence, it is very easy to commit to memory the Daśagītika aphorisms written according to this system. But while this system has some advantage, it has at the same time a very serious drawback. To explain briefly the nature of the system and its inconvenience, an illustration is given below :—

The first half of the first couplet describing revolutions of planets, runs thus :—

युगरविभगणाः ख्युघृ शशि चयगियिङुशुछ्लृ कु ङिशिबुण्लृख्षृप्राक्

The number of revolutions* of 'Ku' (the earth), according to this verse comes to be 1582237500 in a Mahāyuga.

*Āryabhaṭa holds the view that the earth has the diurnal motion and that is why he has given the number of rotations of the earth. Other Siddhāntas give revolutions of stars instead.

Dr. Kern's book gives 'ṣu' in place of 'bu' in this line. 'ṣu' denotes 800000, that is, a number greater by 570000. The misprint of 'ṣu' for 'bu' has caused so much error.	ḍhi = 500 śi = 7000 bu = 230000 ṇḷ = 1500000000 khṣṛ = 82000000 ——— 1582237500

This is an error* occurring in a printed book which is very carefully checked and printed ; what then are the chances of errors having crept in in a manuscript and of these errors getting aggravated by traditional use, can be understood only by those who have occasions to go through manuscripts. Such a work is bound to go out of use in course of time, if there be no means like traditional interpretations, and checks of agreement with other works.

Motions and Revolutions of Planets

After first quoting the two couplets which mention the numbers of revolutions and other elements of planets, the author gives the numbers derived from them. The first part of the first couplet has already been given above. The remaining couplets are given below :—

शनिदुङ्ख्व गुरुखिच्युभ कुजभद्लिझनुख् भृगुबुधसौराः ॥ १ ॥
चंद्रोच्चजुष्खिध बुधसुगुशिषन भृगुजषबिखुछ् शेषार्काः ॥
बुफिनच पातविलोमा बुधान्ह्यजार्कोदयाच्च लंकायां ॥ २ ॥

The revolutions in a *mahāyuga* as derived from these verses are :—

Rotations of the earth	1582237500	Revolutions of Jupiter	364224
Revolutions of the Sun	4320000	Revolutions of Venus	7022388
Number of sāvana days	1577917500	Revolutions of Saturn	146564
Revolutions of the Moon	57753336	Solar months	51840000
Revolutions of the Moon's Apogee	488219	Intercalary months	1593336
Revolutions of the Moon's node	232226	Lunar months	53433336
Revolutions of Mars	2296824	Tithis	1603000080
Revolutions of Mercury	17937020	Suppressed tithis	25082580

Length of the year=365d 15gh 31p 15vp.

The numbers of revolutions given by the original Sūrya Siddhānta on page 23..do not include those for Rāhu, but comparison of the remaining numbers with the above figures from the Āryasiddhānta shows that the revolutions of Jupiter and Mercury are different in the two, while the remaining numbers are the same ; and it has already been shown before, that the original Sūrya Siddhānta existed before Āryabhaṭa. This shows that Āryabhaṭa borrowed the elements of all planets except those for Mercury and Jupiter from the original Sūrya Siddhānta. The elements for the revolutions of Jupiter and Mercury appear to have been adopted by him by experience after testing their accuracy with their observed positions.

*This error cannot be detected from the commentary, but it can be easily found after considering the theory and agreement with other works. However, this error of Dr. Kern will throw several scholars into confusion.

The Yuga System

It has been remarked above that Āryabhaṭa's system is somewhat different from that of the other Siddhāntas. It is as follows. He says in his 'daśagītika' :—

काह्रो मनवो ढ १४ मनुयुगश्ख ७२ गतास्तेच ६ मनुयुगछ्ना २७ च ।।
कल्पादेर्युगपादा ग ३ च गुरुदिवसाच्च भारतात् पूर्वं ।। ३ ।।

"The number of Manus in a Brahmā's day is 'ḍha' (=14). A manu consists of śkha (=72) yugas. The number of manus elapsed from the beginning of Kalpa is 'ca' (=6) and that of yugas elapsed is 'chnā' (=27) ; and the number of yugapādas elapsed, prior to *Thursday*, the beginning day of Bhārata is 'ga' (=3)".

In this verse a Manu is said to consist of 72 yugas and not 71 as in others A 'sandhi'(transition or twilight period) has not been mentioned as to occurring before the commencement of each '*manvantara*'. This verse also tells us what period has elapsed from the commmencement of Kalpa up to *Thursday*, the beginning day of Bhārata*. This verse and the 2nd couplet quoted on page53, show that according to Āryabhaṭa the Kaliyuga started on Friday, and the previous day was a Thursday. But the second couplet quoted above shows that the Mahāyuga** began on Wednesday at sunrise. This shows that Āryabhaṭa does not accept the definitions of time units, *e.g.* a Dvāpara equal to twice Kali, and so on. If these definitions be accepted, the Kaliyuga would not be found to have commenced on Friday, after supposing the yuga to begin on Wednesday. We get the result if all 'pādas' or quarters of a yuga be sup posed to be equal in length .This shows that he regarded Kṛta and other 'uygapādas' as equal in length, and from this assumption it appears that the number of years elapsed, from the commencement of Kalpa to that of the present Kaliyuga, comes to be1986120000 and the Kalpa appears to have commenced on Thursday. The number of years elapsed from the commencement of Kalpa to that of the present Kaliyuga comes to 1972944000† according to other Siddhāntas; and according to some, who suppose that some years were spent at the beginning of the Kalpa or over Creation, it was a Sunday when the planets started to move. Brahmagupta has criticised†† Āryabhaṭa for having entertained this kind of view so different from others.

न समा युगमनुकल्पा: कल्पादिगतं कृतादियातंच ।। स्मृत्युक्तैरार्यभटो नातो जानाति
मध्यगतिं ।। १० ।।

ब्रह्मगु सि. अ. ११.

"The measures of Yuga, Manu, and Kalpa, and the number of Kṛta and other yugas elapsed after the commencement of the Kalpa, are not equal to those mentioned by the Smṛti. This shows that Āryabhaṭa does not know mean motions of planets."

*The word 'Bhārata' stands for 'Bhārata war'. The word is here used in the se of commencement of Kaliyuga.

**Although the word mahāyuga has not been explicitly mentioned, it was evide ly so, as may be seen from context and theory.

†After including the years supposed to have been spent over creation.

††Most of the above facts have been mentioned by Brahmagupta; but instead of placing implicit faith in them, I have actually found them out for myself.

In this verse, Āryabhaṭa has been accused by Brahmagupta of not having given the Yugas, Manu and Kalpa according to the Smṛti. The length of a mahāyuga adopted by him is equal to that given by others. The number of revolutions mentioned above will show that they are divisible by four, and the second couplet says that all the planets were together in the beginning of the mahāyuga. Similarly, according to Āryabhata the 'yugapādas' (*i.e.* parts of a mahāyuga) are all equal ; and in his opinion the number of mahāyugas elapsed between the commencement of Kalpa up to the present Kṛta and other yugas is a whole number. Hence, according to his view, all planets come together at the commencement of each Kalpa, each mahāyuga and also at each Pāda or fourth part of a yuga. He has not at all given the number of revolutions of aphelia and nodes of other planets in a Kalpa. He had no reason to consider, if any years were spent over Creation ; but in his opinion, all planets come together at the beginning of Kalpa. This shows that he did not at all make the assumption that some years were spent in Creation. If he were required to give the number of nodes and aphelia of planets he would have given them on the assumption that the beginning of a Kalpa coincided with the first start of the planets for their movement.

Date

Āryabhaṭa has recorded his date in the following couplet :

षष्ठ्यब्दानां षष्टिर्यदा व्यतीतास्त्रयश्च युगपादाः ॥
त्र्यधिका विंशतिरब्दास्तदेह ममजन्मनोतीताः ॥

कालक्रियापाद

Āryabhaṭa says that he was 23 when sixty 60-year cycles (*i.e.* 3600 years) had elapsed after the three 'yugapādas,' that is, in the 3600th 'Kali-elapsed' year, which is the same as Śaka 421. This shows that his birth year was Śaka 398.

Length of a Year

The length of the year according to the Sūrya Siddhānta of the Pañcasidhāntikā is $365^{d}—15^{gh}—31^{p}—30^{vip}$, and that calculated from the elements given by Āryabhaṭa above comes to be $365^{d}—15^{gh}—31^{p}—15^{vip}$, that is 15 vipalas less. But according to the original Sūrya Siddhānta of the Pañcasiddhāntikā, the Kali yuga commenced at midnight on Thursday ; and Āryabhaṭa has assumed it to begin it at sunrise on Friday, that is 15 ghaṭis later ; but because the length of this year is less by 15 vipalas, the cumulative difference in 3600 years would be 15 ghaṭis less ; and hence, the moment of the mean Sun's entry into Meṣa *i.e.* the moment of the beginning of the elapsed year 3600 after Kali *i.e.* in Śaka 421, according to the original Sūrya Siddhānta and Āryasiddhānta, comes to be the same ; and this shows that he assumed the length of the year to be less by 15 vipalas in order to avoid the discrepancy which would occur, if the yuga be assumed to commence from the sunrise.

If anyone entertains any doubt about his date, the length of the year as given above will leave no room for such doubt. His date of birth is definitely Śaka 398.

Place

Āryabhaṭa observes in the first couplet of his 'Gaṇitapāda'

आर्यभटस्त्विहनिगदति कुसुमपुरेऽभ्यर्चितं ज्ञानं ॥

"Āryabhaṭa, however, imparts the sacred knowledge in this (town of) Kusumapura."

From this, his place of residence seems to be Kusumapura, which is believed to be Patna in Bengal.

Subject Matter

The '*daśagītikāpāda*' of Āryabhaṭa's Siddhānta contains the numbers of revolutions and other elements of planets. The next three pādas are devoted to 'gaṇita' (Mathematics), Kālakriyā (time units) and 'Gola' (celestial sphere). The gaṇitapāda includes some subjects from arithmetic, algebra, geometry and trigonometry from among the branches of pure mathematics ; and the remaining two pādas are devoted to astronomical questions alone. As a matter of fact, according to modern conception, astronomy is a branch of applied mathematics and hence, it need not deal with arithmetic and other branches of pure mathematics; but astronomy often requires the help of pure mathematics; and hence, it is natural for such ancient works to include both types ; but such a combination is found in very few works. We have no means to know if it existed in the original Sūrya Siddhānta ; but it is not found in the Pañcasiddhāntikā and also in modern Sūrya and Soma Siddhāntas. This Āryasiddhānta, the Brahmaguptasiddānta and the second Āryasidhānta, however, do contain pure mathematics also. Bhāskarācārya's definition of a siddhānta has been given above (page xxviii of part 1), according to which he has included in the siddhāntas both the branches of mathematics, viz. 'vyakta' or known (arithmetic) and 'avyakta' or unknown (algebra), and accordingly he calls his two works *Lilāvatī and Bījagaṇita*, as parts of his work, *Siddhānta Śiromani* ; still he has computed them as independent works ; and some referencesin it show that independent works on algebra were already compiled before Bhāskarācārya's time. The two Āryabhaṭas and Brahmagupta have included algebra and other branches of mathematics in the siddhānta itself ; but these subjects have been treated in separate chapters.

The contents of the 'gaṇitapāda' will be briefly described in Āryabhaṭa's work. This pāda consists of 32 couplets in addition to the benedictory verse. It contains the following subjects :—

Place names of digits of numbers, squares and cubes ; square root and cube root ; triangles, circles, and other figures and their areas ; volumes of cubes and spheres; calculation of sines and their brief treatment ; progressions, rule of three, fractions ; an interesting type or two of problems solvable by rule of three or by algebra, and a section of mathematics known as 'kuttaka' (problems of multipliers). These are the topics dealt with in the 'gaṇitapāda'. Ptolemy and the Greek astronomers before his time had no knowledge of the sines. They used to make use of chords. The Europeans, before they studied Indian astronomy, held the view that it was Al Battanī, the Arab astronomer* (who ved in the latter half of the 9th century A.D.) first made use of sines in place

*See page 56, translation of Sūryasiddhānta by Burgess.

of chords. But this work of Āryabhaṭa shows that we knew the use of sines in Śaka 421. Even the modern Sūrya-Siddhānta gives sines. One more thing worth being specially mentioned is that Āryabhaṭa has very accurately given the ratio of the circumference of the circle to its diameter by the following verse :—

चतुरधिकं शतमष्टगुणं द्वाषष्टिस्तथा सहस्राणां ।। अयुतद्वयविष्कंभस्यासन्नो
वृत्तपरिणाहः ।। १० ।।
गणितपाद.

The approximate length of the circumference of a circle whose diameter is 2000 is 62000 increased by "104 multiplied by 8". This gives 62832 as the length of the circumference corresponding to 2000 as diameter, which gives 1:3.1416 as the ratio. Even this has been given by him as only approximate.

DIURNAL MOTION OF THE EARTH

Āryabhaṭa is the only astronomer in our country who holds that the earth rotates round itself; in other words, he holds that the earth has a diurnal motion. He remarks :—

अनुलोमगतिर्नौस्थः पश्यत्यचलं विलोमगं यद्वत् ।। अचलानि भानि तद्वत् समपश्चिमगानि
लंकायां ।।
गोलपाद.

"Just as one, sitting in a boat, observes stationary objects moving backwards; similarly, to an observer in Laṅkā (i.e. equator) the stationary stars appear to be moving towards the West".

The commentator of Bhaṭaprakāśikā has attempted to make out in the following lines that even Āryabhaṭa holds the view that the earth is stationary.

"भानि कर्तृभूतानि अचलानि भूमिगतानि वस्तूनि कर्मभूतानि विलोमगानीव
प्राचीं दिशं गच्छंतीव पश्यंति"*

But Āryabhaṭa instead of giving the revolutions of stars in the list of elements has given the rotations of the earth. He has also remarked at another place (4th couplet of daśagītika) that the earth revolves through one minute of arc in a unit of time known as 'prāṇa' (i.e. $\frac{1}{6}$ of a pala). Similarly, Brahmagupta and others have criticised Āryabhaṭa for holding the view that the earth rotates. Brahmagupta says :—

प्राणेनैति कलां भूर्यदि तर्हि कुतो व्रजेत् कमध्वानं ।। आवर्तनमुर्व्याश्चेन्न पतंति
समुच्छ्रयाः कस्मात् ।।
ब्र. सि. अ. ११.

If it be assumed that the earth does rotate one minute arc in one 'Prāṇa' unit of time, where, then, does it go and by what track, and how is it that objects situated as elevated places do not fall off ?

*Meaning :—The stars, (when they take the place of a 'subject') observe the earthly objects (which became an 'object') as moving towards the east.

Āryabhaṭa might have compiled some Karaṇa work. Āryabhaṭa's conception of the day commencing with sunrise is given by the second couplet from Daśagītika given above (page 53); but Varāhamihira remarks that according to Āryabhaṭa, the day is said to commence even from the midnight at Laṅkā (page 25). This statement of Āryabhaṭa is not found in the Āryabhaṭīya. and even Brahmagupta is not seen to criticise him for this. It proves that even at the time of Brahmagupta, the Āryabhaṭīya did not contain some such couplets. Brahmagupta has referred to the two parts of Āryasiddhānta by these very words, viz. 'daśagītika and āryāṣṭāśata'. From this it appears that no one has added anything to or taken away from the Āryasiddhānta which existed before Brahmagupta. The Varāhamihira's statement, therefore, suggests that Āryabhaṭa must have compiled some other work, and Brahmagupta's Khaṇḍakhādyaka and Varuṇa's commentary on it, lead one to conjecture that there must have existed some Karaṇa work written by Āryabhaṭa. It is, however, not available at present.

Criticism

Brahmagupta has levelled a great deal of criticism against Āryabhaṭa After enumerating different points of criticism, he further remarks :—

स्वयमेव नाम यत्कृतमार्यभटेन स्फुटं स्वगणितस्य ।। सिद्धं तदस्फुटत्वं ग्रहणादीनां

विसंवदति ।। ४२ ।।

जानात्येकमपि यतो नार्यभटो गणितकालगोलानां ।। न मया प्रोक्तानि ततः पृथक्

पृथक् दूषणान्येषां

।। ४३ ।। आर्यभटदूषणानां संख्यां वक्तुं न शक्यते ।।

ब्र. गु. सि. अ. ११.

"Aryabhaṭa himself has claimed the correctness of this calculation; but that calculation has been proved to be incorrect on account of its disagreement with the actual phenomena of eclipses, etc. Since Āryabhaṭa understands nothing of mathematics, celestial sphere or time, I have not mentioned separately his demerits concerning short-comings in respect of other subjects. It is impossible to enumerate all demerits of Āryabhaṭa."

The fact that calculations of eclipses, etc., made from Āryabhaṭa's works showed disagreement with the observed results is worth-considering. Their correctness or otherwise can be judged from some of the points of criticism enumerated above. Although it is true that some of the points are correct. still, Brahmagupta's statement betrays a great deal of prejudice.

Loss of Works

Brahmagupta says :—

कालांतरेण दोषा येन्यैः प्रोक्ता न ते मयाभिहिताः ।।

"I have not repeated the demerits which have been stated by others as time elapsed."

But, of the available works compiled before Brahmagupta, it is only the Pañcasiddhāntikā which mentions Āryabhaṭa's name only, and makes no mention of any of his faults. This shows that some works of pre-Brahmagupta period must have been lost. The works of authors belonging to the period before Śaka 421 and mentioned above are not at present available.

"I have finally corrected* the 'Sun' from the yoga (conjunction) of the sun with the earth, the 'moon' from the conjunction of the moon and the sun; and all the 'planets' from the conjunctions of the moon and stars with the planets. I took out the jewel, in the form of true knowledge, through God's favour or with my own intellectual power, from the ocean of real and false knowledge."

Eclipses and conjunctions can lead us to find even the mean motions; but it is the true place which is chiefly found from them. This verse and the one referred to before this, will show that Āryabhaṭa has made an improvement in the calculation of true places. Similarly, his high capability can be seen from the fact that he made researches by means of observation and intelligence after critically studying the old works with common sense.

ITS INFLUENCE AND FOLLOWERS

Utpala has extracted a number of couplets from Āryabhaṭīya in his commentary on Bṛhatsaṃhitā; and extracts from it are also found in a number of works compiled later on. LALLA, the famous astronomer, was a follower of Āryabhaṭa. He has suggested a correction to the planetary motions given by Āryabhaṭa. The Karaṇa work, named *Karaṇaprakāśa* which belonged to the Ārya-Pakṣa and was compiled in Śaka 1014, has been compiled after applying Lalla's corrections to the planetary places and motions obtained from the elements given by Āryabhaṭa. (This will be explained in detail later on). Similarly, DĀMODARA's Karaṇa work, named *Bhaṭatulya*, which was compiled in Śaka 1339, follows the same method. Many people use Karaṇaprakāśa even now for calculation and many are its followers. The *Grahalāghava* has adopted the positions of Jupiter, Mars and Rāhu from the Karaṇaprakāśa and the Grahalāghava is followed in more than one third part of India.

PLACE

It shows that the Āryasiddhānta is even now followed, if not in its original form, at least with the application of corrections to it. Quotations from Āryasiddhānta are not found in astronomical works which were compiled in Mahārāṣtra and Vārānasī after Śaka 1400. It has already been pointed out above that the Ārya siddhānta is not available on our side in its original form. Dr. Kern has published an Āryabhaṭīya on the basis of three manuscripts obtained by him. All these manuscripts are written in the Malayalam script. This shows that the Āryasiddhānta is still known in South India and specially in the Malabar province. The provinces which speak the Tamil and Malayalam dialects follow the almanac computed on solar basis, and it belongs to the Āryapakṣa, since the year adopted in it is according to the first Āryasiddhānta. The Vaiṣṇavas are adherents of the Āryapakṣa. They form a large part of the population in Karnataka and Mysore. Patna in Bengal (at that time) is believed to be Āryabhaṭa's place; but there is some doubt about it; because, the Āryasiddhānta is not at all in use in Bengal. It appears from this that the Kusumapura mentioned by Āryabhaṭa might be some place in the south; nothing can be, however, said about it for certain.

PLANETARY CORRECTIONS

It has already been pointed out that the places of planets given by the Āryasiddhānta, sometimes tally exactly with those calculated from European tables; but for a clearer understanding and consideration of them, the mean positions of planets true for the mean Sun's entry into Aries of Śaka 421 (i.e. 499 A.D.) as calculated from the *Āryabhaṭīya* and also from the European tables have been given together in a tabular form, on page 62-63

*The first sentence refers to the lunar eclipse and the second to the solar eclipse.

Mean places of planets for 15 Ghaṭikās after sunrise on sunday, Caitra Kṛṣṇa 9, śaka 421.

Planets	Original Sūrya Siddhānta	Variation+ or—from column 12	First Ārya Siddhānta	Variation+ or—from column 12	Five Modern Sūrya & other Siddhāntas	Variation+ or —from column 12
	1	2	3	4	5	6
	s ° ′ ″	° ′ ″	s ° ′ ″	° ′ ″	s ° ′ ″	° ′ ″
Sun	0	0	0	0	11 29 58 37	—0·1 23
Moon	9 10 48 0	—0 4 48	9 10 48 0.	—0 4 48	9 10 29 33	—0 23 15
Moon's Apogee	1 5 42 0	—0 28 30	1 5 42 0	—0 28 30	1 0 53 51	—4 16 39
Rāhu			11 22 12 0	—0 42 18	11 18 36 4	—4 18 14
Mars	0 7 12 0	+0 7 0	0 7 12 0	+0 7 0	0 9 23 16	+2 18 16
Mercury	6 0 0 0	—3 22 12	6 6 0 0	—2 37 48	6 17 54 16	+14 32 4
Jupiter	6 6 0 0	—1 29 54	6 7 12 0	—0 17 54	6 5 59 53	—1 30 1
Venus	11 26 24 0	+0 6 24	11 26 24 0	+0 6 24	11 22 45 45	—3 31 51
Saturn	1 19 12 0	+0 51 54	1 19 12 0	+0 51 54	1 20 23 57	+2 3 51

Planets	Variation in Solar distance as compared with Col. 12	Brahmagupta Siddhānta	Variation+ cr—from Col. 12	Variation in Solar distance as compared with Col. 12	Sāyana places calculated from Keropant's planetary tables	Nirayana places obtained from Col. 11 by applying ayanāmśa correction of +16′ 54″
	7	8	9	10	11	12
	° ′ ″	s ° ′ ″	° ′ ″	° ′ ″	s ° ′ ″	s ° ′ ″
Sun	0	0 0 51 45	+0 51 45	0	11 29 43 6	0 0 0 0
Moon	—0 21 52	9 11 31 46	+0 38 58	—0 12 47	9 10 35 54	9 10 52 48
Moon's Apogee	—4 15 16	1 7 21 3	+1 10 33	+0 18 48	1 5 53 36	1 6 10 30
Rāhu	—4 16 51	11 23 23 14	+0 28 56	—0 22 49	11 22 37 24	11 22 54 18
Mars	+2 19 39	0 8 4 45	+0 59 45	+0 8 0	0 6 48 6	0 7 5 0
Mercury	+14 33 27	6 0 41 2	—2 41 10	—3 32 51	6 3 5 18	6 3 22 12
Jupiter	—1 28 38	6 7 28 9	—0 1 45	—0 53 30	6 7 13 0	6 7 29 54
Venus	—3 30 28	11 26 57 12	+0 39 36	—0 12 9	11 26 0 42	11 26 17 36
Saturn	+2 5 14	1 19 0 1	+0 39 55	—0 11 50	1 18 3 12	1 18 20 6

For a simultaneous comparison of all the works, the places of planets have been calculated from the original Sūrya Siddhānta, the modern Sūrya Siddhānta, and the Brahma Siddhānta for the same moment and have been noted in the same table.

The moment of mean Sun's entry into Aries for the (elapsed year) Śaka 421

works	gh.	pal.	
Original Sūrya Siddhānta . . .	15	0	Time elapsed after mean sunrise at Ujjayinī on Sunday, 9th lunar day of the dark half of 'amānta' Caitra, i.e. the 21st of March.
First Ārya Siddhānta	15	0	
The modern five Siddhāntas (Sūrya and others) .	16	24	
Brahma Siddhānta (Caitra Kṛṣṇa 8, Saturday).	22	30	

The 11th column on page 63 above, gives places of planets as calculated from Keropant's planetary tables ; they are, therefore, as accurate as those calculated from European tables. They are Sāyana. Out of these, the secular equation is applied to the moon, the moon's apogee and the moon's node only. After applying the ayanāṃśa correction of 'plus 16′-54″' in Śaka 421 to the planets in this column, the nirayaṇa positions so found have been given in the 12th column, and the places given by works, like the original Sūrya Siddhānta and others, have been compared with these figures. The precessional motion in 20 years comes to be 16′-54″ ; and taking this figure as the ayanāṃśa for Śaka 421, therefore, is equivalent to taking zero as the ayanāṃśa for Śaka 441. This year is very near to Śaka 444. It is true that the equinox was near the junction-star of Revatī about Śaka 496, and it is suggested that the aynāṃśa for that year should be taken as zero. But it has been pointed out thereafter in the study of the precession of equinoxes that the Indians were right in supposing Śaka 445 as the zero-precession year according to their system. The object of assuming 16′-54″ as the ayanāṃśa, while comparing the figures, is that it would facilitate the comparison with resect to the sun. It is not that there will be much error resulting from this. The error, at the most, would be four minutes of arc.

There is no harm if seconds of arc be neglected while making a comparisons since, they can be said to be carrying no value in the comparison. The sun' longitude as given in columns 1 and 3 is zero ; and hence, the results of comparison of the planets' places in them with those of the 12th column which are noted in columns 2 and 4 are with respect to the planets and to the sun also, which means that the figures in columns 2 and 4 give the differences obtained by comparing the planets' positions independently with those given in column 12. Similarly, the figures in columns 2 and 4 indicate also the differences obtained by comparing the figures, showing positions of planets in column 12 ahead of the sun's position given in it and the figures indicating the advance of planetary positions in columns 1 and 3 over the positions of the sun given in them. The sun's longitude given in cols. 5 and 8, is not zero ; and hence, the differences in the planets' places in these columns, as independently compared with those in the 12th column, have been shown in the 6th and 9th columns; and their differences, when compared with respect to the sun, have been given in the 7th and 10th columns.

The difference in the case of only

given by the original Sūrya-Siddhānta, is greater than one degree, while that of others is less than that. Only Mercury, as given by First Āryasiddhānta differs by more than 2 degrees, while other planets do not differ by more than 51 minutes. Almost all the planets, except the moon, obtained from the modern Sūrya-Siddhānta differ by a considerable quantity. As for the differences in the positions of planets (with respect to the sun) in the case of Brahmagupta Siddhānta and shown in column 10, that of Mercury only is really considerable, that of Jupiter is 53 minutes while that of others is less than 22 minutes of arc.

The whole discussion shows that there is no harm if it be said that the places of planets of all Siddhāntas, except those of modern Sūrya Siddhānta, for Śaka 421, used to prove fairly correct. The position of the moon is no doubt given very accurately by all. All except Brahmagupta, have given the same number of revolutions for the moon; but the moon's place, as calculated from the modern Śūrya Siddhānta has come to be somewhat different from that of others because of different lengths adopted for a year. The discrepancy in the case of Mercury, according to all Siddhāntas, is considerable. The reason for this appears to be that its constant proximity to the sun allows rare chances for its observation.

The method of judging the accuracy or otherwise of astronomical works by comparing the mean places of planets as found from the European and Indian works has been shown to be not without risk in all cases and all circumstances, as explained in the course of the discussion of Bentley's method of determining the date of old works (page 30). But in the absence of any better way of judging how far our works agreed with observations in respect of the results of their calculations, the writer has followed the same method.

The numbers of revolutions and other elements mentioned by our different works have been given before and some more will be given later on. But, the periods of one sidereal revolution as found from European works and our works, have been given further (page 66) in order to facilitate the comparison of the two.

Ptolemy's measures given in it have been taken from the translation of the Sūrya Siddhānta by Burgess, and those for the Sūrya Siddhānta and Brahma Siddhānta (or Siddhānta Śiromaṇi) have also been adopted from the same book. There is, however, probably no error* in them. The figures derived from the *Practical Astronomy* by *Loomis* have been adopted as the modern European measures.

The length of the year, as adopted by our Sūrya Siddhānta, when compared with that of the modern European works, appears to be greater by about 8 palas—34.5 vipalas and that of the Brahma Siddhānta by about 7 palas—25.6 vipalas. Even though the motion of the moon is considerable, there is almost no error in it. The time taken by the moon's node for one revolution is longer by 4 days and that in the case of Saturn is different by 6 days; the discrepancies in the case of others are less than a day.

PTOLEMY

Prof. Whitney observes that he has calculated Ptolemy's elements from the daily motions given by him, after taking into account the precessional motion (of 36″ per year) as adopted by him. They do not at all resemble the elements given by our Siddhāntas. *This proves that our Siddhānta works have not borrowed the places and motions of planets from Ptolemy's works.*

*Even if there be one, no calculation of the author given in this book has been made on the basis of these elements.

Times required for one sidereal revolution

Planets	Modern Sūrya Siddhānta				Brahmagupta Siddhānta				Ptolemy's work				Modern European works			
	Days	gh.	p.	v.	Days	gh.	p.	v.	Days	gh.	p.	v.	Days	gh.	p.	v.
Sun	365	15	31	31.4	365	15	30	22.5	365	15	24	31.5	365	15	22	56.87
Moon	27	19	18	1.6	27	19	18	0.25	27	19	18	0.2	27	19	17	58.866
Moon's apogee	3232	5	37	13.6	3232	44	2	45	3232	24	40	34	3232	34	31	14.088
Meon's node	6794	23	59	23.5	6792.	15	14	14.7	6799	58	16	38.5	6798	16	44	24.000
Mercury	87	58	10	55.7	87	58	11	43.7	87	58	11	47.2	87	58	9	24.998
Venus	224	41	54	50.6	224	41	52	34.7	224	42	9	52	224	42	2	47.486
Māra	686	59	50	5.87	686	52	52	33.7	686	58	49	50.2	686	58	46	2.518
Jupiter	4332	19	14	20.9	4332	14	24	19.2	4332	45	22	56.2	4332	35	5	17.49
Saturn	10765	46	23	4.1	10765	48	54	51.2	10758	44	30	37.2	10759	13	10	57.49

Aphelia and Nodes in Śaka 421 (i.e. Kali elapsed year 3600)

Planets	From Keropant's planetary tables	First Ārya Siddhānta: Place	First Ārya Siddhānta: Variation from Keropant	Modern Sūrya Siddhānta: Place	Modern Sūrya Siddhānta: Variation from Keropant	Brahmagupta Siddhānta: Place	Brahmagupta Siddhānta: Variation from Keropant
1	2	3	4	5	6	7	8
Apsides	s ° ′	s °	° ′	s ° ′	° ′	s ° ′	° ′
Sun	2 17 7	2 18	+ 0 53	2 17 15	+ 0 8	2 17 54	+ 0 47
Mars	4 8 11	3 28	—10 11	4 10 1	+ 1 50	4 8 23	+ 0 12
Mercury	7 24 1	7 0	—24 0	7 10 26	— 13 35	7 14 53	— 9 8
Jupiter	5 20 38	6 0	+ 9 22	5 21 16	+ 0 38	5 22 31	+ 1 53
Venus	9 21 3	3 0	—201 3	2 19 49	—211 14	2 21 14	—209 59
Saturn	8 5 12	7 26	— 9 12	7 26 37	— 8 35	8 20 54	+ 15 42
Nodes							
Mars	1 8 9	1 10	+ 1 51	1 10 5	+ 1 56	0 21 55	— 16 14
Mercury	1 0 18	0 20	— 10 18	0 20 44	— 9 34	0 21 12	— 9 6
Jupiter	2 25 30	2 20	— 5 30	2 19 41	— 5 49	2 22 2	— 3 28
Venus	2 3 40	2 0	— 3 40	1 29 46	— 3 54	1 29 49	— 3 51
Saturn	3 10 13	3 10	— 0 13	3 10 25	+ 0 12	3 13 13	+ 3 0

APHELIA & NODES

The positions of aphelia and nodes of all planets according to different authors at the commencement of the Kaliyuga and those for the year Śaka 421 (i.e. Kali elapsed year 3600) have been given respectively in tables on pages 67 and 68. Prof. Whitney, after giving the aphelia and nodes according to Ptolemy and the Sūrya Siddhānta together, has suggested that the Hindus must have taken them either from Ptolemy or from other earlier Greek works. But the following comparative table shows that this statement is incorrect, as can be seen from the positions of aphelia and nodes according to Ptolemy and also the figures for the same for Ptolemy's time i.e. the year 148 A. D. (Śaka year 70) as calculated from *Keropant's* planetary tables which give modern European figures.

A comparison of Ptolemy's figures for the Apsides and Nodes (in Śaka 70) with those calculated from Keropant's tables :—

	Apsides			Nodes		
		Ptolemy's work			Ptolemy's work	
Planet	(Sāyana) from Keropant's tables	Position	Diff. with Keropant's place	(Sāyana) from Keropant's tables	Position	Diff. with Keropant's place
1	2	3	4	2	3	4
	s ° '	s ° '	° '	s ° '	s ° '	° '
Sun . .	2 11 5	2 5 30	— 5 35			
Mars . .	4 1 39	3 25 30	— 6 9	1 5 29	0 25 30	— 9 59
Mercury .	7 18 32	6 10 0	— 38 32	0 26 5	0 10 0	—16 5
Jupiter . .	5 15 7	5 11 0	— 4 7	2 22 1	1 21 0	—31 1
Venus . .	9 16 18	1 25 0	—231 18	2 0 39	1 25 0	— 5 39
Saturn . .	7 28 45	7 23 0	— 5 45	3 7 28	6 30 0	+85 32

The positions for apsides and nodes according to our old works (as shown on pages 67 and 68) at the commencement of Kaliyuga and in the Kali elapsed year 3600 will show that the variation during 3600 years is very small; and the reason for this is their very slow motion. None of our Siddhāntas mention the motion of the apsides and nodes as greater than 1 degree in 13000 years. The figures calculated from Keropant's tables and shown in the two tables above show that, if the equinox be taken to be the initial point, in other words, if the sāyana system be followed, the motion appears to be considerable ; but the motions appear to be negligibly small if sidereal i.e. the nirayaṇa basis be adopted.

The table on page 70 , gives the annual motions of apsides and nodes very accurately calculated by modern European methods following the sāyana system and also the actual yearly motion* according to the nirayaṇa system.

*These have been taken from Practical Astronomy by Loomis.

Yearly motions of Apsides and Nodes.

	According to European Calculations			
Planets	Sāyana	True Nirayaṇa	That which must be adopted according to our Nirayaṇa system	According to the Sūrya-Siddhānta
1	2	3	4	5
Aphelia	Seconds	Seconds	Seconds	Seconds
Sun	+61.5	+11.24	+ 1.5	+0.1161
Mars	+65.7	+15.46	+ 5.7	+ .0612
Mercury	+56.1	+ 5.81	— 3.9	+ .1104
Jupiter	+56.9	+ 6.65	— 3.1	+ .27
Venus	+47.0	— 3.24	—13.0	+ .1605
Saturn	+69.6	+19.31	+ 9.6	+ .0117
Nodes				
Mars	+25.0	—25.22	—35.0	—0.0642
Mercury	+40.2	—10.07	—19.8	— .1464
Jupiter	+34.3	—15.90	—25.7	—.0522
Venus	+29.7	—20.50	—30.3	— .2709
Saturn	+30.7	—19.54	—29.3	— .1986

This motion has been calculated after assuming 50.2″ as the equinoctial motion ; but our works have assumed 60″ as the equinoctial motion. Hence. the motion shown in column 4 is the actual annual motion according to our works ; and if the figures denoting motions according to European works are to be compared at all, they should be compared with this motion. Even when the comparison is so made, the motions according to the Sūrya Sidhānta are found to be very erroneous. The motions according to other Siddhāntas can also be said to be equally erroneous. None of the other works gives for the annual motions of an aphelion or node, a figure greater than one third of a second. It is greater than 1 second according to the European system. It is very easy to criticise our works regarding this discrepancy, simply by seeing the figures on papers. But he who knows how difficult it is to observe an arc of one second in the sky even with the help of very accurate modern instruments will not blame them in that way. It has been observed by the author with naked eyes some conjuctions of planets with stars, and it has been our experience that those two planets etc. which are actually apart from each other by 5 minutes (300 seconds) of arc or more, as observed through a telescope appear to be in close contact with each other as seen with naked eyes, in other

words, there appears to be no distance between them. Hence, this fact should be borne in mind while comparing the figures of our works with accurate measures of European works and we must praise our works instead of condemning them regarding the apsides and nodes. We should appreciate the authors of our works, in as much as they recognized the fact that the motions of apsides and nodes are very small. It should only be seen as to how much accurate the longitudes of the apsides and nodes calculated from their works, prove to be. The postions of the apsides and nodes in Śaka 421, have been given above (page 68) and their differences obtained after comparison with the figures calculated from Keropant's tables, have also been given. It shows that the positions given by our Siddhāntas are very near to actual positions. Keropant-calculation gives sāyana results, but since the ayanāṃśa in Śaka 421 was about 20 minutes only, there is no harm in comparing the figures taking them as nirayaṇa. The Sun's apogee, in fact, shows only a very little error ; but the aphelion of Venus, however, shows a considerable error. Its cause is not known ; it is a problem worth considering. But looking to the remaining aphelia, it appears that the aphelion of Mercury, according to First Āryabhaṭa, is less by 24 degrees, while others differ within 10 degrees. Those of Sūrya Siddhānta are more accurate than these, that of Mercury being less by 13 degrees and that of Saturn less by 8 degrees. The aphelia of Mars and Jupiter show only a small difference. Those mentioned by Brahamagupta are as accurate as in the Sūrya Siddhānta or even more so. The table given on page 69 compares Ptolemy's aphelia with those derived by Keropant's calculation. These positions given by Ptolemy were presumably sāyana like his other positions and the fact is corroborated from the positions of the sun's apogee and hence, there is no harm, if the figures are compared with Keropant's sāyana calculations ; and the comparison reveals that even his position of the aphelion of Venus is considerably wrong and his aphelia on the whole show greater errors than those in the Sūrya Siddhānta and Brahma Siddhānta.

The nodes given on page 68 show an average error of 4° in Āryabaṭa's places. Those of the Sūrya Siddhānta are in error by 4°, those of Brahma gupta by 7° and those mentioned by Ptolemy (page 69) are erroneous by as many as 30 degrees. The nodes of Jupiter and Saturn given by him are considerably wrong. The position of the sun's apogee as given by him is 65° 30′. The sāyana position of the sun's apogee in his time i.e. about 150 A.D. comes to be 71°. By no other method can one possibly get 65°30′ as its position. None of our Siddhāntas show an error of more than 1° in the sun's apogee. The error of 5½ degrees committed by Ptolemy, is very surprising. The statement of Prof. Whitney that the Hindus borrowed the figures for apsides and nodes from the positions given by Ptolemy or by some earlier Greek writers is, therefore, incorrect. He has never himself compared the positions of the apsides and nodes calculated from European tables for Ptolemy's time, or for Śaka 421 or for any other time. He himself says that finding their positions involves a very intricate and laborious calculation*. But it is not particularly difficult. Looking to Whitney's general ability, it can be said that the calculation of the places was not a difficult task for him. He has certainly, not considered the matter properly, and an inference drawn, without making proper comparison, is bound to be mistaken. The very differences of 3 to 82 degrees between Ptolemy's figures and those of our works in the positions of apsides and nodes, show that the two have absolutely no connection. The position of the sun's apogee alone will prove this. The sun's

*Translation of the Sūrya Siddhānta by Burgess, p. 283.

apogee according to the writers of our Siddhāntas has remained near about 78 degrees from Śaka 421 to this date. It is not known since how long it had remained there before the date. Different Siddhāntas differ widely from one another in respect of the places of aphelia of other planets but not in the case of the sun. Had the Hindus borrowed the positions of apsides from Ptolemy's work, how could they have changed the position of the sun's apogee from 65° to 78° ?. It will be seen at different places in this work that, while borrowing the positions of planets from other works, the authors of our works do not allow a discrepancy even in seconds. This shows that the apsides mentioned by our works have been independently calculated. Even the apsides and nodes of the authors of our own Siddhāntas differ considerably amongst themselves. This shows that even the authors of our Siddhāntas did not borrow figures from one another, but each of them found them out independently. Whitney remarks that "the Hindus were not capable enough to derive such data as the apsides and nodes for themselves or to modify or improve them when borrowed from other sources, according to the lapse of time"; but on the contrary, this very charge can be made against Ptolemy. The sun's apogee 65°30′ given by Ptolemy was correct for the times of Hipparchus who lived in 150 B. C. It shows that Ptolemy might have taken the figure without applying a suitable correction for his time. Calculation shows that the aphelia and nodes of other planets also agree with those true for the time when Hipparchus lived. It appears from this that Ptolemy might have adopted even these from the figures in use in the time of Hipparchus without applying suitable corrections. But no information is at present available to show what positions for the apsides and nodes were assumed in the time of Hipparchus or before him and hence nothing can be said with certainty about this. It is left to the readers to consider, if the Hindus could have borrowed the positions of apsides and nodes either from Ptolemy or from earlier Greeks* when the figures for apsides and nodes giver by Ptolemy were so erroneous and had no similarity with those obtained from Hindu works, and when it is not known at present what positions were accepted in Ptolemy's time. Ptolemy's figures showing the positions of apsides and nodes which were possibly borrowed by him from Hipparchus, and those derived from our old works differ from 3° to 30° in the case of the apsides and from 4° to 82° in the case of nodes. If we assume that the Hindus adopted these figures in their works after applying a suitable correction to Hipparchus figures, basing their calculation on the changes in both, which took place within a period of 650 years, which elapsed from the time of Hipparchus (150 B.C.) to Śaka 421 (500 A.D.), the difference ought to have been uniform throughout, but it is not so, and had they assumed the difference to be due to their motion in 650 years they would have given a larger figure for the motions of the apsides and nodes, but they mention a figure which is less than 1° in 13000 years. This shows that the Hindus did not borrow the apsides and nodes even from the works of the Greeks who lived earlier than Ptolemy. There is another proof that the authors of our Siddhāntas found out the positions of apsides and nodes true for their times independently. There are no means to know, if the original Sūrya-Siddhānta had given revolutions of apsides and nodes in a Kalpa or not. The Pañcasiddhāntikā does not give these. First Āryabhaṭa has not given also, but he has given their positions for his time. This shows that he must have come to know that the motions of apsides and nodes, if they had any, were extremely slow, but he has not given the revolutions of their motions in a yuga, as they could not be detected in a short period. Bhāskarācārya, while

*This remark is based on Whitney's statement.

describing the method of finding the position of the sun's apogee at a given time, observes about its motions as follows :—

उच्चस्य चलनं वर्षशतेनापि नोपलक्ष्यते किन्त्वाचार्यैश्चंद्रमंदोच्चवदनुमानात् कल्पिता गतिः सा चैवं ।।

मंभगणैः सांप्रताहर्गणाद्वर्षगणाद्वा एतावदुच्चं भवति ते भगणा युक्त्या कुट्टकेन वा कल्पिताः ।।

The purport of the lines is given below :—

"The motion of an aphelion can not be detected even in centuries. But the motions of the moon's apogee do come to notice. Assuming that the sun's apogee may also have a similar motion, the author arbitrarily took such a number for revolutions as would give correct position* for the desired moment." Bhāskarācārya has written that similar method should be followed in the case of the aphelia and the nodes of other planets also. It shows that the authors of our Siddhāntas knew how to find the positions of the apsides and nodes at a particular time and they have accordingly found the figures for their revolutions. *This proves that the writers of our Siddhāntas have independently found out positions of the apsides and nodes for their times.*

VARĀHAMIHIRA

His Date

He was a famous astronomer, who compiled works on all the three branches of astronomy. Let us consider his probable date. He has nowhere mentioned his date explicitly. But he has already mentioned in his Karaṇa work. named Pañcasiddhāntikā that he has adopted Śaka 427 as the starting year He must have been at least 20 years old, if he had compiled the work then. It is impossible that such a work could have been written at an earlier age and from this we can take Śaka 407 as the approximate year of his birth. A line is often quoted in support of the date of his death. It runs as follows :—

नवाधिकपंचशतसंख्यशाके वराहमिहिराचार्यो दिवं गतः ।।

which means that Varāhamihira passed away in Śaka 509. It is not known if this line was originally in prose or in metric form, if in metric form, it is extremely incorrect. According to some, this line is quoted by PṚTHŪSVĀMI, the commentator of Brahmagupta. The anthor has gone through the Pṛthūdaka-commentary of the first ten chapters of Brahmagupta's Siddhānta, but he has not come across this line in it. He has not read the commentary on *Golādhyāya* and other chapters following the first ten. He is unable to say, if the line is given in this commentary or in that of Khaṇḍakhādyaka. This Pṛthūdaka lived about the Śaka year 900. If the line was written by Pṛthūdaka himself, it must have been written 400 years after Varāha and hence it requires very careful scrutiny for its acceptance in the face of Śaka 427 given by Varāha himself.

According to Prof. Weber**, it is the statement of ĀMARGJA, the commentator of Brahmagupta that Varāhamihira died in Śaka 509. He has not given the original quotation, but it must pobably be the same as above. It is, thereefor,

*The apsides were assumed to be at the first point of Aries in the beginning of Kalpa.

** *See* footnote 293 in Weber's book.

doubtful if the line is the quotation of Pṛthūdaka or of Āmarāja. Weber has quoted another statement of Āmarāja that ŚATĀNANDA was born in Śaka 917. But the work, *Bhāsvatīkaraṇa* of Śatānanda has taken Śaka 1021 as the epochal year. There is no other well known Śatānanda. From this, Āmarāja's statement about Śatānanda appears to be quite incorrect ; and hence, if it is made by Āmarāja at all, it also deserves little or no consideration. The second point to be considered, is that Āmarāja's statement carries little weight since he lived after Śaka 917, that is 4 or 5 centuries later than Varāhamihira. Considering also the correctness or otherwise of our manuscripts, if the above quoted line be in prose, it leaves room for doubt, if it has come down to us in its exact form. It is, therefore, clear that it is better to accept Śaka 427 which is given in his own work and which leaves no room for any doubt according to planetary positions given in it, as more reliable than to say, after relying on such a quotation, that Varāhamihira died in Śaka 509. It is true that the Śaka year which is adopted by a Karaṇa work need not be the year in which the work was completed. Thus Keropant's work has given examples for Śaka 1772, though it was printed in Śaka 1782. In the same way, Varāha's work could have been completed after Śaka 427. Even then, the calculations concerning the work might have started in Śaka 427 or in about a year or two before or after it. Otherwise there seems to be no other reason for adopting Śaka 427 as the epochal year. If he was not born in Śaka 427, there was no possibility of adopting that Śaka. This shows that he was not born after Śaka 427 ; not only this but it is felt that he must have been at least 15 or 16 years old in that year, and he must have selected that year for solving examples ; and that is why the year appears in the work. There is no other probable reason for its mention in it. The mean sun's entry into Aries occurred nearabout the first lunar day of the light half of Caitra (*i.e.* amānta Vaiśākha) in Śaka 427 ; and he must have adopted the year Śaka 427, because it was convenient to calculate the mean positions of planets for the moment and to describe the method of calculating ahargaṇa from the 1st lunar day of the light half. It is just possible that the work might have been actually compiled even later. But even then, the mean sun's entry into Aries apears to have occurred near about the first lunar day of the light half in Śaka 419 before Śaka 427 and in Śaka 438 before that year. The year 419 need not be considered at all and the figure 438 has not been adopted. This shows that the work was completed before Śaka 438. The Pañcasiddhāntikā mentions Āryabhaṭa's name and his work was compiled in Śaka 421 ; hence, one may be led to raise the objection that there was hardly any possibility of Āryabhaṭa's work having become so famous in a period of 6 years ; but the objection is not worth much consideration. Varāha's work could possibly have taken 4 or 5 years more after Śaka 427 for completion. It is, therefore, not quite impossible for the well known astronomer, devoted to the same work and residing in the famous city of Avantī, to have noticed Āryabhaṭa's work or to have known his viewsr It appears for certain that in Śaka 427, Varāhamihira was old enough to be able to do calculations. If, therefore, it be supposed that he was 15 years old in Śaka 427, his year of birth comes to be Śaka 412 and if Śaka 509 be supposed to be the year of his death, his age at death comes to be 97 which is not an impossibility. The birth-year of Varāhamihira, then, from all considerations comes to be about Śaka 412. It is just possible that he adopted Śaka 427 as the starting year, because it was his year of birth. There is however, no doubt that his birth year is not later than Śaka 427.

The following verse from the work, *Jyotirvidābharaṇa*, shows that Varāhamihira was one of the nine gems at the court of Vikrama, *i.e.* near about the commencement of the Vikrama era :—

धन्वंतरिक्षपणकामरसिंहशंकुवेतालभट्टघटखर्परकालिदासाः ।।
ख्यातो वराहमिहिरो नृपतेः सभायां रत्नानि वै वररुचिर्नव विक्रमस्य ।।

The famous Varāhamihira was one of the nine gems at the court of KING VIKRAMA. *These nine gems were :—Dhanvantarī, Kṣpaṇaka, Amarasiṃha, Śaṃku, Vetālabhaṭṭa, Ghaṭakharpara, Kālidāsa, Varāhamihira* and *Vararuci*".

It has been mentioned in this work that it was compiled by the famous poet Kālidāsa who composed the poems "Raghu", "Kumāra", etc. and the verse.

वर्षैः सिंधुरदर्शनांबरगुणै ३०६८ र्याते कलौ संमिते मासे माधवसंज्ञिते च विहितो
ग्रंथक्रियोपक्रमः ।।

This work was begun in Kali-elapsed year 3068, in the month name Mādhava.

It is stated in the verse that the work was commenced in 3068 elapsed from Kali, that is, in Vikrama Samvat 24. But it also describes the following method of finding ayanāṃśas for a particular year.

शाकः शरांभोधियुगो ४४५ नितो हृतो मानं खतर्कै ६० रयनांशकाः स्युः ।।

Subtract 445 from the Śaka number (of the year concerned) and divide (the remainder) by 60, and the result would be the ayanāṃśa. Also, the first chapter contains the word मवा वराहमिहिरादिमतैः meaning, 'as accepted by Varāha and others" and hence this work cannot be relied upon. If some other Varāhamihira had lived about the commencement of Vikrama era, as mentioned in this work, he must have been a different person from the compiler of the Pañcasiddhāntikā*

HIS LINEAGE, RESIDENCE, ETC.

Varāhimihira observes in Bṛhajjātaka,

आदित्यदासतनयस्तदवाप्तबोधः कापित्थके सवितृलब्धवरप्रसादः ।।
आवंतिको मुनिमतान्यवलोक्य सम्यग्घोरां वराहमिहिरो रुचिरां चकार ।। ९ ।।

उपसंहाराध्याय.

*The late Raghunāth Śāstrī Tembhūkar, an astronomer of Poona, gave me a verse about the date of Varāhamihira, which he reported to me to have taken from the Kutūhala Mañjarī, belonging to Rājārāma Vyankateś Śāstrī of Bidar. The verse runs thus :—

स्वस्तिश्रीनृपसूर्यसूनुजशके याते द्विवेदांबरत्रै ३०४२ मानाब्दमिते त्वनेहसि जये वर्षे वसंतादिके ।। चैत्रे श्वेतदले शुभेवसुतिथावादित्यदासादभूद्वेदांगे निपुणो वराहमिहिरो विप्रो रवेराशिभिः ।।

(*Meaning* :—The Brāhmaṇa 'Varāha' son of Ādityadāsa and proficient in Vedāṅgas, was born with the blessings of the god Sun, on the 8th lunar day of the light half of Caitra, in the year named Jaya, in the Yudhiṣṭhira Śaka 3042). Varāhamihira, the author of Pañcasiddhāntikā also was "son of Ādityadāsa, who got him with the blessings of the god Sun',' But the year mentioned in this verse does not agree with calculation by any method whatsoever ; hence, the verse is not reliable.

"Varāhamihira, who was the son of Ādityadāsa, from whom he obtained knowledge, who was blessed with the god Sun at Kāpitthaka and lived in Avantī, compiled this beautiful 'horā' work, after studying the views of sages".

This shows that Ādityadāsa was the name of his father, from whom he mastered all knowledge. He received blessings from Sun at Kāpitthaka and was the resident of Ujjayinī. Kāpitthaka must be a place near about Avantī, and he might have lived there for some time. That he was the devotee of Sun, is apparent from the prayers chiefly offered to Sun god in the benedictory verses he has given at the beginning of all his works. The following verse from the Pañcasiddhāntikā shows that his tutor in astronomy was a preson different from his father :—

दिनकरवसिष्टपूर्वान् विविधमुनीन् भावत: प्रणम्यादौ ।।

जनकं गुरुं च शास्त्रे येनास्मिन् न: कृतो बोध: ।। १ ।।

अध्या. १.

That he was the resident of Ujjayinī can be seen from 4 or 5 of his references made elsewhere.

FOREIGN TRAVEL.

Some people are found to believe that Bhāskarācārya went to Greece to learn 'astronomy'. But, looking to his works and to those of his earlier writers, this belief appears to be quite baseless. The same remark is also made about Varāhamihira by some. But his works and Bhaṭotpala's commentary on them show that works on all the subjects deat with by Varāhamihira in his works existed in plenty in our country before him and hence he had no reason to go to a foreign country.

HIS WORKS

He has compiled works on pilgrimage (travel), marriage, mathematics (Karaṇa), Horā (astrology), and Saṃhitā (Astronomy). His famous work on the Saṃhitā branch, known as *Bṛhatsaṃhitā* was compiled by him after all other works as can be seen from his own remark made in the Bṛhatsaṃhitā.

वक्रानुवक्रास्तमयोदयाद्यास्ताराग्रहाणां करणे मयोक्ता: ।

होरागतं विस्तरतश्च जन्म यात्राविवाहै: सह पूर्वमुक्तं ।। १० ।।

अध्या १.

"I have treated in my Karaṇa work the questions of direct and retrograde motions, the rising and setting of planets and luminaries ; the work on Horā-branch which includes the description of birth in detail, has already been described along with the subjects on travel and marriage".

The work on Horā-branch, alluded to by him, in the above verse, refers no doubt, to the Bṛhajjātaka. The following verse from the Bṛhajjātaka shows that the works on marriage and Karaṇa preceded the Bṛhajjātaka while that on travel (yātrā) followed it.

अध्यायानां विंशतिः पंचयुक्ता जन्मन्येतद्यात्रिकं चाभिधास्ये ।। ३ ।।
...विवाहकालः करणं ग्रहाणां प्रोक्तं पृथक् तद्विपुला च शाखा ।। ६ ।।

बृ. जा. उपसंहाराध्याय.

"The group of three (subjects) which I will describe along with the subject of birth, have been given in 25 chapters....the subject of marriage, and that of the calculation of planets, which are described independently, form 'extensive branches"

The karaṇa work referred to in it is the Pañcasiddhāntikā itself. It does not refer to any other work compiled earlier. This consideration and the consideration of his age lead one to believe that the Pañcasiddhāntikā itself was Varāha's first work. Utpala's commentary on chapter 1, of the Bṛhatsaṃhitā, shows that his work on marriage was known as Bṛhadvivāhapaṭala. This work and his work on pilgrimage are not available at present. He has compiled a work named Laghujātaka on Horā branch in addition to his Bṛhajjātaka; he remarks in it,

होराशास्त्रं वृत्तैर्मया निबद्धं निरीक्ष्य शास्त्राणि ।।
यत्तस्याप्यार्याभिः सारमहं संप्रवक्ष्यामि ।। १ ।।

" After studying the scientific works compiled on the subject of astrology (Horā), I describe their summary in Āryā metre."

CIRCULATION OF WORKS

This shows that the Laghujātaka is the abridged edition of Bṛhajjātaka. From all considerations *the order of his works* seems to be as follows :—

Pañcasiddhāntikā, Vivāhapaṭala, Bṛhajjātaka, Laghujātaka, Yātrā, Bṛhatsaṃhitā. The Laghujātaka, in this, might have been probably compiled after Yātrā and Bṛhatsaṃhitā. The works, Bṛhajjātaka and Laghujātaka are very much in use amongst astrologers even to this day ; and both of them have been printed at Bombay, Poona, Vārānasī and other places and might have been published in several places in different scripts. Dr. Kerne has published only the text of the Bṛhatsaṃhitā and its English translation in the 5th volume of the Royal Asiatic Society. The text of the Bṛhatsaṃhitā has been published in the Bibliothica Indica at Calcutta. The Jaganmitra press of Ratnagiri has published the text of Bṛhatsaṃhitā along with its Marāṭhi translation.

COMMENTARY

Bhaṭotpala is the famous commentator of Varāha. The Bṛhatsaṃhitā and the Bṛhajjātaka being very useful works, have remained in use up to this day. Even then, it may also be said that Utpala's commentary has specially been the cause of their popularity. Utpala, in his commentary on the Bṛhatsaṃhitā, in the discussion on 'Nīrājana vidhi', remarks "commented in detail under the question of travel" which shows that Utpala has written a commentary on the work on pilgrimage. He wrote a commentary on the Laghujātaka also. Other works of Varāha do not appear to have been commented upon by Utpala. The date of Utpala's commentary comes to about Śaka

888 *i.e.* about 400 years after Varāha. His remark "others hold this view" in the commertary on Rāhucāra and at other 2 or 3 places, show that there were other commentaries on the Bṛhatsaṃhitā before Utpala's time. The commentaries on the Bṛhajjātaka by Mahıdāsa ard Mahıdhara are in the Deccan College collection (*See* Nos. 341, 343 of 1882—83 A.D.).

DESCRIPTION OF HIS WORKS

A more detailed description of the Bṛhatsaṃhitā, the Bṛhajjātaka and the Laghujātaka will be given later on. A description of the Pañcasiddhāntikā, his works on mathematical-branch, has been given before in almost full details. The remaining points will be dealt with here.

A verse has already been given above which remarks, "I have described in the Karaṇa work the questions of retrograde and direct motions, setting and rising of plantets, etc." Later on he observes,

युद्धं यदा यथा वा भविष्यमादिश्यते त्रिकालज्ञैः ।। तद्विज्ञानं करणे मया कृतं

सूर्यसिद्धांतात् ।।

बृ. सं. अ. १७.

"I have incorporated from the Sūrya Siddhānta in my *Karaṇa work*, the knowledge of predicting, like the seers of the three times (past, present and future) when and how war will take place."

And all these questions have been dealt with by him in the Pañcasiddhāntikā. This remark and other proofs also show that the Pañcasiddhāntikā itself was his Karaṇa work (*i.e.* a work on practical mathematics). Nowhere ir the book has he mentioned Pañcasiddhāntikā as its name.

अष्टादशभिर्बध्वा ताराग्रहतंत्रमेतदध्यायैः ।।
भजते वराहमिहिरो ददाति निर्मत्सरः करणं ।। ६५ ।।

पं. सि. अ. १८

"Free from jealousy Varāhamihira has given this excellent short treatise on the planets comprised in 18 āryās."

In this, he calls the work as a Karaṇa and a Tantra. He has, at one more place in the Pañcasiddhāntikā, called the work a *Karaṇa* or a *'Tantra'*. Utpala has given the name of Pañcasiddhāntikā to the work. It has already been pointed out that he has translated the five Siddhāntas. He has recommended his own corrections to be applied to the mean positions of planets mentioned by the Sūrya Siddhānta.

क्षेप्याः धारेंदु १५ विकलाः प्रतिवर्षं मध्यमक्षितिजे ।
दश १० दश गुरोर्विशोध्याः शनैश्चरे सार्धसप्त ७।३० युताः ।। १० ।।
पंचद्वया २५ विशोध्याः सिते बुधे खाश्विचंद्र १२० युताः ।।

"The following corrections should be applied to mean places of planets :— 15 seconds per year should be added to Mars ; 10 to be deducted from Jupiter ; $7\frac{1}{2}$ to be added to Saturn ; 25 to be subtracted from Venus and 120 to be added to Mercury.'

It has already been shown above that none of the Siddhārtas of the Pañca-siddhārtikā was compiled by Varāhamihira and these corrections prove the fact beyond doubt. Had the places and motions of planets giver in any one of them been calculated by him, there was no need of mentioning the corrections. It has been pointed out before that the elements given in Bhāsvatī karaṇa tally after these corrections are applied.

Varāhamihira has mentioned the mean places from different Siddhāntas. The explanation of eclipses is also given in different ways from different works.. However, the following verses from chapters 1 and 18 show that in mentioning them it was Varāha's intention to show that he has rectified in his work those items which the earlier authors of Tantras were unable to do.

यत्तत्परं रहस्यं भ्रमति मतिर्यंत्र तंत्रकाराणां ॥
तदहमपहाय मत्सरमस्मिन् वक्ष्ये ग्रहं भानोः ॥ ५ ॥
दिक्स्थितिविमर्दकर्णप्रमाणवेलाग्रहाग्रहाविंदोः ॥
ताराग्रहसंयोगं देशांतरसाधनं चास्मिन् ॥ ६ ॥
सममंडलचंद्रोदय यंत्रछेद्यानि तांडवछाया ॥
उपकरणाद्यक्षज्यावलंबकापक्रमाद्यानि ॥ ७ ॥

अध्याय १

प्रद्युम्नो भूतनये जीवे सौरे च विजयनंदी ॥ ५९ ॥
भग्नावतः स्फुटमिदं करणं दृष्टं वराहमिहिरेण ॥

अध्याय १८

The above verses mean :—

(No. 5) "That subject which is the greatest mystery, which perplexes the minds of the writers of astronomical works, *viz.* the eclipse of the sun, I am going to explain in this work, dismissing all jealousy."

(No. 6) "Moreover these are contained in this work, the (rules for the calculation of the) direction, the duration, the period of total obscurity, the hypotenuse, the time of the measures (*i.e.* beginning, middle and ending of eclipses) of the eclipses or (eventual) non-eclipses of the moon, the conjunctions and obscurity of stars and planets, the means of finding the difference in longitude."

(No. 7) "The prime vertical, the rising of the moon, the construction of astronomical instruments; the shadow of the gnomon; other useful matters; the sine of the terrestrial latitude; the sine of colatitude; the declination and other subjects."

Similarly,

(No. 59) "This Karaṇa work has been accurately compiled by Varāhamihira, since Pradyumna broke down in his efforts (over the calculation) of Mars and Vijayanandī over that of Jupiter and Saturn."

It, therefore, shows that he must have done something more than the original works included in the Pañcasiddhāntikā. The corrections to mean planets mentioned above is one of such items. There are no means to know

what the other items were. It is not, however, possible that he might have made great changes in the original. It appears that he retained those things from the five Siddhāntas which, he thought showed an agreement with experience, and those general methods which were theoratically sound in his opinion and omitted the remaining matter. It seems also possible that he must have evolved his own methods concerning the questions of 'deśāntara' (difference in longitude) calculation of chāyā (shadow) ; grahaṇa (eclipses) and chedyaka (projections).

He at first compiled the Karaṇa work. But later on his Saṃhitā works show that his attention was drawn very much to astrology and various natural phenomena, properties of matter and their utility in everyday life. Brahamagupta has crticised earlier astronomers, but has nowhere criticised Varāhamihira.* Bhāskarācārya has praised him and has taken Varāhamihira's quotations in support of his statements in a number of his works. There have been several authors who wrote on 'astronomy' as a branch of *natural science*, but it can be said that there has been no other astronomer after Varāhamihira who has himself treated several branches of natural science itself. It is a matter of pride to us that such a scholar lived in our country in such an ancient time. But while his works on astrology have been found very useful to this day, his works on Saṃhitā have neither been much studied nor been used to that extent. Had the studies of properties of matter continued on the same line without any break, the Europeans could not have surpassed us in this field. But it is misfortune of our country that the tradition was not continued.

ŚRĪṢEṆA AND VIṢṆUCANDRA

These astronomers lived sometime after Varāha and before Brahmagupta, that is, between Śaka 427 and 550. Their works are not now available. The view, that the Romaka and Vasiṣṭha Siddhāntas were either compiled by them or with the help of their works, have already been considered before.

BRAHMAGUPTA

Date

Brahamagupta writes in his work, *Brāhmasphuṭasiddhānta*

श्रीचापवंशतिलके श्रीव्याघ्रमुखे नृपे शकनृपाणां ।।
पंचाशत्संयुक्तैर्वर्षशतैः पंचभिरतीतैः ५५० ।। ७ ।।
ब्राह्मः स्फुटसिद्धांतः सज्जनगणितगोलवित्प्रीत्यै ।।
त्रिंशद्वर्षेण कृतो जिष्णुसुतब्रह्मगुप्तेन ।। ८ ।।

From this it seems that Brahmagupta compiled this work in Śaka 550 when King Vyāghramukha of Cāpa dynasty was ruling. His father's name was Jiṣṇu. Brahmagupta was 30 years old when he wrote Brahma Siddhānta in Śaka 550, which shows that his birth year was Śaka 520.

*Brahmagupta has criticised Varāhamihira for not stating that Rāhu, who envelops the moon while it enters the earth's shadow, was the main cause of the eclipse ; but this is really not a defect ; and in reality even Brahmagupta did not mean to blame him.

in Bṛhatsaṃhitā a number of couplets from Brahmagupta Siddhānta and he has referred to all such places in such words as 'Brahma Siddhānta' or 'so says Brahmagupta'. Nowhere has Utpala referred to these couplets as 'from Brahma Siddhānta of Śākalya' or 'from Brahma Siddhānta included in Viṣṇudharmottara Purāṇa'. This shows that the two Siddhāntas, it existing then at all, were not much known ; and according to Utpala, at any rate the Brahmagupta Siddhānta was the one compiled by Brahmagupta. Even Brahmagupta calls his Siddhānta everywhere Brahmasphuṭa Siddhānta or simply Brahmasiddhānta. The author has also called this Siddhānta 'Brahma Siddhānta' for convenience in this work.

Elements

The numbers of revolutions and other elements mentioned in the Brahma Siddhānta are given below :—

	In a Kalpa which is a period of 4320000000 years			
	Measures like sāvana days, etc.	Revolutions in longitudes	Revolutions of	
			apsides	nodes
Revol. of stars	1582236450000			
The Sun		4320000000	480	
Sāvana days	1577916450000			
Moon		57753300000		
Moon's apogee		488105858		
Moon's ascending node		232311168		
Mars		2296828522	292	267
Mercury		17936998984	332	521
Jupiter		364226455	855	63

	In a Kalpa which is a period of 4320000000 years			
	Measures like sāvana days, etc.	Revolutions in longitude	Revolutions of	
			apsides	nodes
Venus		7022389492	653	893
Saturn		146567298	41	584
Solar months	51840000000			
Intercalary months	1593300000			
Lunar months	53433300000			
Tithis	1602999000000			
Suppressed tithis	25082550000			

	d	gh	p	vip	pvp
Length of the year =	365	15	30	22	30

All the measures in this table are given for a *Kalpa*. No number can be found which can completely divide the numbers denoting the revolutions of all planets, and hence, according to this Brahma Siddhānta the mean planets cannot all come together at one place, at any moment other than at the beginning of Kalpa. All the planets come together by mean motions at the beginning of *Kaliyuga* according to the first Ārya Siddhānta or the two Sūrya Siddhāntas, but they are not so conjoined according to the Brahma Siddhānta. This Siddhānta does not, like the modern Sūrya-Siddhānta, assume any period spent over creation. According to this, the moment of commencement of the Kalpa coincides with that of the planets starting to move.

Length of Year

The first thing to be remembered is that the length of the year, *viz.* 365d 15g 30p 22vip 30pvp, as adopted by this Siddhānta, is less than that adopted by any Indian Siddhānta except the Puliśa and Romaka of the Pañcasiddhāntikā. It has been clearly pointed out in the discussion of the ancient and modern groups of five Siddhāntas that the Puliśa and Romaka Siddhāntas of Pañcasiddhāntikā were not in use in Brahmagupta's time. The *first* Ārya Siddhānta and *original* Sūrya Siddhānta were in use in his time. Of them, Brahmagupta's length of the year is shorter than that of the original Sūrya Siddhānta by 67¼ vipalas and by 52½ vipalas than that of the first Ārya Siddhānta. This difference appears to be very small, but because of this (small) variation the moment of the mean sun's entry into Aries in Śaka 540, according to Brahmagupta, occurred 54gh 14⅛ pals earlier than that according to the first Ārya Siddhānta and 54gh 43⅞ pals earlier than that according to the original Sūrya Siddhānta. What then is the cause of this variation ? The cause seems to be only one that he assumed the solar ingress into Aries to have occurred on the day on which the day and night were of equal length, *i.e.* on the equinoctial day, when the sun rises on the horizon exactly in the east. This moment of the solar ingress is nothing but the entry of the sun in the sāyana (tropical) sign of Aries. The moment of the sun's actual entry into the tropical sign of Aries on or about the day when Brahmagupta might have taken actual observation, coincided with the moment of the same phenomenon as calculated from Brahma Siddhānta. The moment of the true sun's entry into Aries in Śaka 509, as calculated from Brhamagupta Siddhānta comes to be 56gh—40p after mean sunrise at Ujjayinī on Tuesday, the 3rd lunar day of Caitra Śukla, the 18th March 587 A.D. ; and the time of the entry of the sun into sāyana Aries (*i.e.* sun's longitude being 0ˢ 0° 0′) comes to be the same moment on the same day during that year.*. Brahmagupta was born in Śaka 520. He might have begun the taking of observations from about Śaka 540. Hence, the calculation, according to Brahmagupta, for the year Śaka 540, shows that the apparent Aries ingress appears to have occured at 57gh—22p (after sunrise) on Saturday, the first lunar day of the dark half of Caitra and the tropical

*The sāyana calculations have been made with Keropant's Planetary Tables. As these Tables are not quite accurate, the phenomenon will perhaps be found to occur a year earlier or later. Similarly, the secular equation has not been applied to the sun's place in the above calculation, it would come to about two minutes, which may cause a variation of a year or two.

longitude of the sun comes to be 0s 0° 30′, which shows that the sāyana Aries ingress took place about 30gh before the moment calculated from Brahma Siddhānta. But the sun's declination increases only by 12 minutes in 30 g hatis nearabout the equinoctial time. Hence, in Śaka 540, the sun must have been to the north of the equator by 12 minutes at the moment of the sun's entry into Aries according to Brahma Siddhānta, and if the sun had cometo the first point of Aries (Meṣa Saṃkramaṇa) according to Brahmagupta, at sunrise, the sun's centre would have appeared 12 minutes to the north of the east point. But it is not that the equinox always takes place at the time of sunrise. Any one experienced in the taking of observations will easily admit that an error of 12 minutes arc is possible because errors of some minutes can occur in the determination of directions and also the fact that the instruments of observations used to be crude ; and these considerations lead me to be convinced that he must have taken the sun's entry into the tropical sign of Aries as the moment of Meṣa Saṃkrānti. He ovserves in the Siddhānta,

यदि भिन्ना: सिद्वांता भास्करसंक्रांतयोपि भेदसमा: ॥
स स्पष्ट: पूर्वस्यां विषुवत्यर्कोदयो यस्य ॥ ४ ॥

अ. २४.

"If Siddhāntas are different, so must be the moments of the sun's entry into signs ; but when the sun is on the equator, it is actually seen rising exactly in the east."

The purport of the verse is that the moments of the sun's crossing as seen in the sky will not appear* to be occuring at different moments. This refers to the sun at the time of sunrise on the equinoctial day. It is clearly the place of the tropical sun and Brahmagupta has clearly recorded the place by actual observation. Brahmagupta did not know that the equinox has motion and even if it were known before his time, he undoubtedly did not take it into consideration. Hence, he does not differentiate between the sāyana place of the sun and that found by calculation from his works (*i.e.* nirayaṇa). He attempted to see that the place calculated by his work will exactly tally with that of the tropical sun ; but this was a correct step only so far as his own time was concerned. The reason for this is that though equinox occurred 54 ghaṭis before the calculated time, but yet he could not ignore the traditional belief that the mean sun was at the first point of Aries at the commencement of the Kaliyuga (*i.e.* at sunrise, on Friday, according to his view). He, therefore, distributed the error of 54 ghaṭis over the period of 3730 years (the period between the commencement of Kaliyuga and the date of compilation of the Brahma Siddhānta) and he so effected the adjustment that his work should give the moment of equinox to tally with the entry of the sun into the tropical sign of Aries, that is, the moment when the sun actually appeared to rise exactly in the east. This adjustment diminished the length of the year only by a few vipalas. If he had not to encounter the difficulty of distributing the error over the period from the Kaliyuga to his own date, and if he had just considered how much earlier than a particular date the equinox had begun to occur in his time, he would have done one of the two things—accepting, for the length of a year, the measure of the tropical solar year, *viz.* 365d 14gh 32p, or to retain the traditional length of the year and to assume some motion for the equinox. He compiled the work *Khaṇḍakhādyaka* 37 years after the

*It is because of this kind of disagreement that he remarks "Brahma Sidhānta is the only real siddhānta, while others are more compilations" and often criticises other siddhāntas. The Saṃkrānti according to others, occurs later by one day than according to his work.

Siddhānta and he adopted in it the length of the year given by the original Sūrya Siddhānta. This shows that he must have inclined to adopt some motion for the equinox after retaining the length of the year once adopted or even after being convinced that he must adopt, the actual measure of the tropical year, as the length of the year ; he was not bold enough to discard the traditional length of the year and to alter the one already adopted by him while compiling the Siddhānta. Bhāskarācārya has remarked " how is it that proficient astronomers like Brahmagupta have not mentioned the equinox* ?" It shows that Brahmagupta's original works make no mention of the equinoctial motion.

Sāyana

Whether the almanac should follow the sāyana or the nirayaṇa system is at present a matter of controversy. A point favourable to the followers of the sāyana system is noticeable in the above discussion, and it is that it was Brahmagupta's original view that the sun's entry into a tropical sign was the actual '*saṃkramaṇa*' and it was his desire to alter the length of the year, which he did accordingly. Had he carried on observations throughout his life and compared the results, it was not impossible for a scientist like him to hit upon the correct measure of the tropical year. It may be that he might have come to know it and still was not bold enough to discard the traditional one. The reason for his measure of a year which is shorter than that of others, has not been explained by the author because he was a follower of the sāyana system. Even the staunchest follower of the nirayaṇa system will have to admit its corrections.

Correcting the Planetary Elements and Observations

The numbers showing the revolutions of planets etc., as given by the Brahma Siddhānta are somewhat different from those of the other Siddhāntas. However, the comparison of mean places of planets in Śaka 421 obtained from the Brahma Siddhānta with those of modern European works (page 63) shows that there is not much difference between them. It shows that Brahmagupta adjusted the numbers of planetary revolutions so that the calculated planetary positions for his time would agree with observations. The result of the comparison of apsides and nodes made on page 68 above also shows his independent research in that direction. Hence, the length of the year, the numbers showing revolutions of planets, nodes and apsides, point to the fact that Brahmagupta was an independent research worker who used to take observations for himself ; and this is the main important factor in astronomy. His works reveal at several places the spirit of independence and self-resp e expected of such a personality. He says in the Chapter on true places,

ब्रह्मोक्तमध्यरविशशितदुच्चतत्परिधिभिः स्फुटीकरणं
कृत्वेवं स्पष्टतिथिर्दूरभ्रष्टान्यतंत्रोक्तैः ॥ ३१ ॥

अ. २.

" The true places obtained from the elemen[illegible] like epicycles, aphelia and the mean sun and the mean moon, as mentioned by Brahm[illegible]sphutasiddhānta give the correct tithi ; that obtained from other tantras is far from accurate."

*See Golabandhadhikāra—commentary on couplets 17-19.

He maintains here that the tithi calculated from other tantras is far from accurate and that the tithi calculated on the basis of the sun and the moon according to Brahma Siddhānta is correct.

आर्यभटस्याज्ञानान्मध्यममंदोच्चशीघ्रपरिधीनां ।।
न स्पष्टा भौमाद्याः स्पष्टा ब्रह्मोक्तमध्याद्यैः ।। ३३ ।।

ब. २.

" The true places of Mars and other planets calculated from the ignorant Āryabhaṭa's work giving mean positions of planets, aphelia and epicycles. prove to be wrong, they are found correct when calculated from the mean positions and other elements given by Brahma Siddhānta."

Here he maintains that the positions of Mars and other planets are correct when calculated from the aphelia, epicycles and mean planets according to Brahma Siddhānta but are incorrect according to Āryabhaṭa. There are many such instances showing his pride. This pride has, in some cases, run to such excess, that one cannot help feeling that it is little short of arrogance. He has appended in his Siddhānta an independent chapter, named, 'dūṣaṇādhāya' (No. 11) consisting of 63 couplets. Some of the charges levelled against Āryabhaṭa in it show sheer obstinacy on his part.

Subject matter of Brahma Siddhānta

He has incorporated in the first ten chapters of his Siddhānta, the chapters which are usually found occurring in almost all the Siddhāntas and been enumerated in the 'Introduction of this book'. But he has treated many more subjects in the next 14 chapters and they are very important. One of them is the chapter of criticism. One deals with *arithmetic* and another with *algebra*. Yet another describes *instruments*. Most of the remaining chapters are devoted to the theory underlying the subjects dealt with in the first half. The 12th chapter is devoted to arithmetic, mensuration etc. the56 couplets of which, include almost all the questions dealt with in *Bhāskarācārya's 'Līlāvatī'* The 18th chapter mainly treats of algebra, and contains 102 couplets, but nowhere does it actually mention the word algebra. The chapter is entitled '*Kuṭṭaka*'. It contains a number of subjects found in Bhāskarācārya's 'Bījagaṇita' (algebra). It contains a chapter headed '*Kuṭṭaka*' and it is given, mainly for being used in the calculation of mean places of planets etc. in astronomy. The Brahma Siddhānta has 24 chapters and contains 1008 Couplets.

Commentary

The Deccan college collection has a copy of the commentary by PṚTHŪDAKA on the first ten chapters. Colebrooke has recorded that he had obtained the complete commentary. Colebrooke translated the portions dealing with arithmetic and algebra from the Brahma Siddhānta into English in 1817.

Interpolation and Yogas

Brahmagupta has mentioned the number of verses at the end of every chapter. He seems to have taken this precaution, because he knew from

xperience that changes are often made later in the original. In spite of this recaution there appears to be a discrepancy in respect of a few couplets in he work. Three couplets are actually found in the book without any comnentary but they are not found at all in the commentary by Pṛthūdaka. One of the three couplets in the chapter on true places is particularly noteworthy ince it deals with Viṣkambha and other yogas. It describes the method of alculating yogas, but it is not found in the annotated edition. One is, thereore, inclined to believe that Viṣkambha and other 26 yogas which form a art of the present almanac, did not exist in Brahmagupta's time, that is to say. Vyātipāta, Vaidhṛti and other yogas did not exist in his time. They are not given even in the Pañcasiddhāntikā. This point will be discussed elaorately in the study of almanacs.

Khaṇḍakhādya

It is now proposed to review briefly his work 'Khaṇḍakhādya'. The name 'Khaṇḍakhādya' is strange and the object of giving such a name is not known. This has two parts Pūrva (first) and Uttara (second). The first part consists of 9 chapters which contain 194 couplets. The second par consists of 5 chapters comprising of 71 couplets. Brahmagupta observes n part one, at the very outset ;

वक्ष्यामि खंडखाद्यकमाचार्यार्यभटतुल्यफलं ।। १ ।।

प्रायेणार्यभटेन व्यवहारः प्रतिदिनं यतोऽशक्यः ।।

उद्वाहजातकादिषु तत्समफललघुतरोक्तिरतः ।। २ ।।

"(1) I compile the work, Khaṇḍakhādya, which gives results equivalent to those given by the great scholar, Āryabhaṭa (2) Since it is impossible to carry on every day affairs with Āryabhaṭa's work, this work is being compiled so as to give easily equally accurate results relating to matters like birth, marriage and the like."

In these verses he states that he is compiling a Karaṇa work, the calculations from which give equally correct results, or in other words which would give places of planets similar to those obtainable from the Āryabhaṭa's work which is impossible to use in day-to-day life. The Khaṇḍakhādya has adopted the length of the year (365^{d}—15^{g}—31^{p}—30^{vp}) given by the original Sūrya Siddhānta and not that of the Ārya-Siddhānta ; and hence, he had to assume the beginning of the yuga at midnight and not at sunrise as assumed by him in his own Siddhānta, or as in the Ārya Siddhānta. The epoch in Khaṇḍakhādya is Śaka 587, and the apparent first lunar day of the light half of Vaiśākha (according to the 'amānta' system) falls on Sunday in that year. The epochal positions in it are true for the midnight of Saturday, the new moon day of amānta Caitra i.e. for the midnight preceding Sunday ; and the ahargaṇa is to be calculated from that moment. The mean Aries Ingress according to the original Sūrya

Siddhānta falls at 12ᵍ—9ᵖ* on the same Saturday. The epochal positions given are as follows :—

	s	°	′	″		s	°	′	″
Sun	0	0	32	22	Mercury	9	0	44	49
Moon	0	9	9	43	Jupiter	6	4	25	16
Moon's apogee	10	8	28	9	Venus	10	0	19	14
Rāhu	0	18	47	23	Saturn	9	6	41	16
Mars	3	10	13	6					

If the places of planets, true for the midnight of Saturday, the Caitra Amāvasyā of Śaka 587, be calculated on the basis of the numbers of revolutions and other elements given before on page 23—from the original Sūrya Siddhānta, all of them except the moon's apogee and node, are found exactly to agree with the above positions. They do not agree with those calculated from the Ārya Siddhānta. It appears from this that the Khaṇḍakhādya-Karaṇa agrees with the original *Sūrya Siddhānta* with respect to all items like the length of the year, the initial moment for computing ahargaṇa and almost all the epochal positions. The revolutions of the moon's nodes are not met with in the original *Sūrya Siddhānta*. The place of moon's apogee does not agree with that of the original Sūrya Siddhānta, but it does not also agree with those of the Ārya Siddhānta or the Brahma Siddhānta. The moon's node too does not agree with either of the last two works. As the length of the year and the initial moment of the year adopted for Khaṇḍakhādya were different from those adopted in the Brahma Siddhānta, it is clear that it was no use adopting for Khāṇḍakhādya the moon's apogee and node adopted in the Brahma Siddhānta. It is true that the Khaṇḍakhādya does not agree with the Āryabhaṭa Siddhānta completely ; still, as some of the elements in the Āryabhaṭiya were equal to those in the original Sūrya Siddhānta, the mean positions of planets calculated from Khaṇḍakhādya for Śaka 587, almost resembled those rom the Ārya Siddhānta.

Brahmagupta, observes in the very beginning in the latter portions of the Khaṇḍakhādya, that he would describe the method of finding apparent places of planets because those calculated from Āryabhaṭa's work did not agree with observation. On this, Varuṇa, the commentator, remarks, " Brahmagupta has declared that he was going to compile a work as good as that of Āryabhaṭa, and he did the same in the first half of the work. In the second half he has mentioned an equation from his own Siddhānta to ensure results agreeing with observation. Now only those things which have not been mentioned therein, should be accepted from Āryabhaṭa's Karaṇa work ". This remark and other chapters in the second half show that he has made only such changes while compiling the Khaṇḍakhādya as would give accurate results comparable by observation. He has borrowed the following important items from Āryabhaṭa's work ; the length of the year, mean motions of planets, their epochal positions and the moment of the beginning of yuga. The above remark of Varuṇa and other things show that Āryabhaṭa's work, referred here, is not his Siddhānta now available, but this Karaṇa work.

*It has been mentioned in the account of Varāhamihira that an epoch wherein the moment of mean Aries Ingress nearly coincided with the moment of the new moon was selected as a convenient moment by the Pañcasiddhāntikā also. The two resemble each other in other respects also.

It is really strange that instead of compiling a Karaṇa work equal in merit to his own Siddhānta, he porposed to compile a work and for the most part did compile one equal in merit to that of a staunch rival like Āryabhaṭa on whom he had showered a shower of criticism. There are two reasons for this, one of them must be the fect that Āryabhaṭa's work might have been so popular that he was unable to ignore it and the second reason was that in Śaka 587 when he compiled the Khaṇḍakhādya, the moment of Aries Ingress according to his own Siddhānta occurred 55gh—36$\frac{5}{8}$pals before that of the original Sūrya Siddhānta and 54gh—55$\frac{7}{8}$ pals before that of Āryabhaṭīya. And because of this much difference, the two works would show different intercalary months. The difference in intercalary month and the occurrence of the saṃkrānti a day earlier, arethings easily noticeable even by an ignorant person; and these created an unfavourable public opinion with regaid to the introduction of the mesure of his own Siddhānta. These two reasons, it appears, could not make him bold enough to compile a '*karaṇa*' which would be equal in merit to his own Siddhānta, when Brahmagupta could not introdus his own year—measure, because his saṃkrānti differed by about less than a day, it is worth considering how dificult is would be to bring into use either Keropant's almanac, whose saṃkrānti occurs about 4 days ealier than that of the old works or the sāyna almanac, whose saṃkrānti takes place about 22 days earlier .

Commenmentaries on Khaṇḍakhādya

Varuṇa and Bhaṭotpala have written commenmentaries on Khaṇḍakhādya. Pṛthūdaka too is likely to have written one, but it is nowhere available. One more incomplete commentary has been found which does not mention the name of the commentator ; but he appears to be one from Kashmir as can be seen from the Śaka year 1564 adopted for solving examples, and from the fact that the corrections adopted for longitudes of placcs and the ascensional differencess refer to Kashmir. The Deccan college collection has got a copy of the work entitled *Pañcāṅga Kautuka* (No. 537 of 1875-76 A.D.) which gives tables and methods of calculating figures for almanacs very easily. It has adopted Śaka 1580 as the epoch and the whole calculation has been made with the help of Khaṇḍakhādya. It does not mention that it is compiled in Kashmir; but it was found in Kashmir and it was made use of the popular local era prevalent in Kashmir. It clearly shows that the author belonged to Kashmir. It also shows without doubt that the Karaṇa, Khaṇḍakhādya, was in use in Kasmir till Śaka 1580; and from the three above mentioned commentaries on Khaṇḍakhādya and from the fact that the copies of the Pañcāṅga Kautuka' in the poona college collections were found in Kashmir, it is felt that it must be still in use in that province. Bhāskarācārya has refered to Khaṇḍakhādya. Albiruṇī, (Śaka 950) had obtained the Khaṇḍakhādya and quoted from it.

Spread of Brahma Siddhānta

The fact that Brahmagupta complied Khaṇḍakhādya as a work different from his own Siddhānta shows that he was not sure that he would get any follower for the Siddhānta; and it is natural, as can be seen from following well known remark of Kālidāsa. .

आपरितोषाद्विदुषां न साधु मन्य...विज्ञानं ॥

"No performance should be regarded as excellent, until it satisfies the learned".

The verse gives Leo as the rising sign, whose duration on that day was the period between 4—9 ghatis after sunrise. This planetary condition is impossible for any day other than this in these two years. The moon's position mentioned in the verse, is not found to be true for any other day being earlier or later by one day. The object of mentioning this here is that these planetary positions agree only if the length of the year given by Brahmagupta in his Brahma Siddhānta be accepted and by that of no other Siddhānta. The sun, according to the Sūrya Siddhānta, appears to belong to Gemini on Thursday, the 5th lunar day of Āṣāḍha (Kṛṣṇa), and goes in to Cancer at about 5 ghatis after sunrise, on Friday. By no other Siddhāntas does it appear to be occupying Cancer on Thursday. The saṃkrānti, according to Brahma Siddhānta, appears to occur 61gh 31pal earlier than the saṃkrānti of the modern Sūrya Siddhānta in that Śaka year. Similarly, even Mars appears to be occupying the sign of Capricorn on Thursday according to the modern Sūrya Siddhānta and that of Sagittarius according to the Brahma Siddhānta. In short, the planetary positions are seen to agree quite well according to Brahma Siddhānta and even the consideration of the matter from several points of view leaves no doubt* about it. It proves beyond doubt that the Brahma Siddhānta was in use in its original form in Śaka 819. This old work was compiled in the Deccan when the King Akālavarṣa of Rāṣṭrakūṭa dynasty was ruling the Deccan. From this it appears that the Brahma Siddhānta was in use in its original form in the Deccan in Śaka 819. The corrections in it have been introduced by some one else later on.

Corrections

Varuṇa's commentary on the Brahma Siddhānta appeared about Śaka 962. It does not refer to any corrections. The work Rājamṛgāṅkakaraṇa was compiled in Śaka 964 and it mentions the correction. It appears to have been first introduced then. The corrections include that for even the sun. This correction has changed his length of the year from the original Brahma Siddhānta viz. from $365^{d}—15^{gh}—30^{pal}—22^{vip}—30^{pvp}$ to $365^{d}—15^{gh}—31^{pal}—17^{v}$ks. that is, it is greater than that of the first Āryabhaṭa by about 2 vipalas. The worry of the Brahmapakṣa compiled after this date are found to be in conformed with the corrected Brahma Siddhānta. The Rājamṛgāṅka compiled in Śaka 964 is the first of such Karaṇa works. The second one is the Karaṇa work named 'Karaṇa Kamalamārtaṇḍa' compiled in Śaka 980. The next one, compiled after this in Śaka 1105 is the Karaṇakutūhala of Bhāskarācārya. The Mahādevī Sāraṇī, a work on planetary calculations, compiled in Śaka 1238 and the two works Kheṭakasiddhi and Candrārkī of the astronomer Dinakara and compiled in Śaka 1500, conform to the corrected Brahma Siddhānta. Of them, the Karaṇakutūhala is still in use in some places. The author of Grahalāghava has borrowed some positions of planets as in accordance with the Brahmapakṣa, and these have been taken from the Karaṇakutūhala. The Brahma Siddhānta might have remained in use in its original form up to Śaka 1000 at the most. It may have gone out of everyday use after Bhāskarācārya. Not only that, but because Bhāskarācārya's Siddhānta Śiromaṇī could serve the purpose as efficiently as the Brahma Siddhānta, it appears that Brahma Siddhānta itself might have gone out of use gradually. The quotations from he Brahma Siddhānta are rarely found in works compiled after Bhāskarā-

*The original verse as given in this book is very incorrect. This verse and the one corrected by me along with its explanation, may be seen on page 429—30 of Prof. Bhandarkar's Report on the search for Sanskrit manuscripts for the year 1883—84.

cārya. The work *Brahma Siddhānta* is at present not found anywhere in Mahārāṣṭra, and the same may be true of other provinces as well.

Condition of Astromomy

There is no harm in saying, on the whole, that all the branches of the system which go to make the science of astronomy in our country, appear to have been completely established in the time of Brahmagupta. The necessary variations in the positions of planets were made from time to time later on. It can safely be said that no special reform or research was afterwards made in the system except that of the equinoctial motion. It has already been pointed out above that Brahmagupta was an independent thinker as far as the revolutions of planets, the aphelia and nodes were concerned. The elements concerning the calculations of the true places of planets appear to be his own. Even in 'tripraśnādhikāra' (Adhikāra on three problems) he appears to show a greater skill than earlier writers. He has described the instruments of observation and it is my opinion that the "*turīyayantra*" (the Quadrant instrument) was his invention. The subject of Algebra is not found in any of the earlier works, which shows that he may probably be its originator. Sūryadāsa, the son of Jñyānarāja, the author of the work, Siddhānta-Sundara, wrote commentary in Śaka 1460 on Bhāskarācāryas Algebra. He regards Āryabhaṭa as the oldest writer on Algebra. The work of Āryabhaṭa I may be said to contain no discussion on Algebra ; but that of Āryabhaṭa II does contain it. But it will be shown later that this work is more modern than that of Brahmagupta. Hence the information available at present leads one to conclude that Brahmagupta was the first writer on Algebra. He has not recorded in his work any boastful remarks in the chapter on Bījagaṇita that it was he who discovered the subject anew.From this it can be conjectured that the subject might have been known even before his time. But books are not available. Brahmagupta, was on the whole, a very ingenious research worker. Even a scholarlike Bhāskarācārya has praised him thus "May the work of jiṣṇuja (i.e. the son of Jiṣṇu, Brahmagupta) who is the supreme mathematician, succeed". Similarly, at another place, he remarks, "when after a long lapse of time, a great deal of discrepancy will be caused, men of genius possessing the ability of Brahmagupta, will come to birth, and studying the planetary motions evolved by Brahmagupta, will compile work on these scieencs". It is quite proper that he has been acclaimed as "a great discoverer of (correct) positions and motions of planets and a very intelligent author of scientific works."

LALLA (ABOUT ŚAKA 560)

Works

A work, 'dhīvṛddhidatantra', on planetary calculation stands to his credit-Sudhākara Dvivedī, procured it, and got it printed in Vārānasī, in 1886 A.D. He has written a Muhūrtawork, named 'Ratnakośa'.

Date

Lalla has not mentioned his date or place of his residence. In the chapter on mean places, in Dhīvṛddhidatantra, he remarks,

विज्ञाय शास्त्रमलमार्यभटप्रणीतं । तंत्राणि यद्यपि कृतानि तदीयशिष्यैः ।
कर्मक्रमो न खलु सम्यगुदीरितस्तैः । कर्म ब्रवीम्यहमतः क्रमशस्तदुक्तं ॥२॥

"Although his disciples, after completely studying the scientific works by Āryabhaṭa, have compiled the "*tantra*" *works*, they have not described the methods of calculation in proper manner. Hence I am properly describing in brief the methods".

He has mentioned, in the Uttarādhikāra, corrections to be applied to planets obtained from the Āryasiddhānta. They are :—

शाके नखाब्धि ४२० रहिते शशिनोक्षदस्रै २५ स्ततुंगत: कृतशिवै ११४ स्तस: षडंकै: ।। ६ ।।
शैलाब्धिभि: ४७ सुरगुरोर्गुणिते सितोच्चात् शोध्यं त्रिपंचकु १५३ हते भ्रशराक्षि २५०
भक्ते ।। १ ।।

स्तंबरेमांबुधि ४८ हते क्षितिनंदनस्य सूर्यात्मजस्य गुणितेबरलोचनै २० श्च ।।
व्योमाक्षिवेद ४२० निहते विदधीत लब्धं शीतांशुसूनुचलतुंगकलासुवृद्धिं ।। १९ ।।
इति...ग्रहकर्म दृकप्रभावत् ।। २० ।। आसीदशेषबुधवंदितपादपद्म:...... ।।
शाम्बस्ततोजनि जनेक्षणकैरवेंदुर्भट्टस्त्रिविक्रम इति प्रथित: पृथिव्यां ।। २१ ।।
लल्लेन तस्य तनयेन शशांकमौले: शैलाधिराजतनयादयितस्य शंभो: ।।
संपूज्य पादयुगमार्यभटाभिधानसिद्धांततुल्यफलमेतदकारि तंत्रं ।। २२ ।।

"(18 & 19) Subtract 420 from the Śaka year. The corrections for the planets are as follows :—Moon,—25′ ; Moon's apogee,—114′ ; Moon's node,—96′ ; Jupiter,—47′ ; Venus,—153′ ; Mars,+48′ ; Saturn,+20′ and Mercury, +420′ (20) This, the calculation of planets. . .as suppported by observation. (21) There lived one,. . Śāmba by name, who was revered by all learned men, and from him was born one, known as Trivikrama Bhaṭṭa in the world and who was the "moon for lilies in the eyes of the people". (22) His son Lalla who worshipped the feet of Śiva, the moon-crested Lord and the beloved of Pārvatī complied a 'tantra' equal in merit to the Āryabhaṭa-Siddhānta."

The numbers of revolutions and other elements given in Lalla's works all agree with those of Āryabhaṭa I ; and Lalla has given only the corrections mentioned in the above verses, 18 and 19. From this it is clear that he lived after Āryabhaṭa I. Some evidence is available to determine his date.

The above verse, relating to corrections, has been given in his commentary by Paramādīśvara, the commentator of Āryabhaṭa. There he describes him in the words "tacchiṣyo Lallācāryaḥ", calling Lalla as Āryabhaṭa's disciple. From this and mainly from the method of applying corrections in which 420 has been asked to be subtracted from Śaka, Dr. Kern thinks that the date of Lalla may be Śaka 420 itself. Even the late Janārdana Bālājī Modaka expreses the same view (See Sṛṣṭijñāna monthly, August, 1885, p. 120). There may be many others holding the same view, but they are incorrect. The first reason is that if Lalla had been Āryabhaṭa's disciple and his contemporary, he would not have committed errors in trifling matters which have been pointed out by Bhāskarācārya about Lalla. These errors do not exist in the works of Āryabhaṭa I. The second reason is that if the date of Lalla had been Śaka 420, Brahmagupta would have played seriously in condemning Lalla's works which contain many faults, inasmuch as he (Brahmagupta) has fired volleys of criticism against the works of Āryabhaṭa I even when they do not contain many faults. But the Brahma Siddhānta contains neither Lalla's name nor any of his view. The third reason is that an occasion for applying a correction to a siddhānta does

not arise at the very time of its compilation. Some one suggests a correction to a work only when a perceptible difference in the planets' places, as obtained from the work, comes to notice. Āryabhaṭa compiled his work in Śaka 423, and it is quite impossible that his disciple began to make changes in it from that very date. Had it been the case, Āryabhaṭa himself would have given revolutions (of planets) after taking into consideration this correction. The method of finding Lalla's correcticns requires one only to subtract 420 from the Śaka year ;but it does not mean from this that the corrections were made in that year. The corrections suggested to the Brahma Siddhānta have to be applied from the beginning of Kaliyuga. Similarly, corrections to modern Sūrya Siddhānta are to be applied from the beginning of Kaliyuga. It will, therefore, be ridiculous to say, that becuase of this fact, the corrections came into existence in the beginning of Kaliyuga. The statement that Lalla's corrections were suggested in Śaka 420, is equally ridiculous. One more evidence may be added to this. It is as follows :—

Lalla observes, in the Chapter on "misconceptions"

यदि च भ्रमति क्षमा तदा स्वकुलायं कथमाप्नुयुः खगाः ॥ ४२ ॥

"If it be accepted that the earth rotates, then how can the birds flying in the sky, find their own nests ?"

In this, Lalla has criticised those who maintain that the earth rotates. But it is only Āryabhaṭa I who states that the earth rotates. It is, therefore, not probable that his own disciple would hold the opposite view or at any rate criticise him. On the whole, Lalla cannot be the disciple of Āryabhaṭa. Bhāskarācārya's works mention Lalla's name at several places ; but nowhere has he mentioned him as Āryabhaṭa's disciple or even merely as a disciple. Raṅganātha, the commentator of Sūrya Siddhānta, has at one place mentioned "śiṣyādhīvṛddhi-datantra" which simply means' a 'tantra' work which increases the intellectual power of disciples". It is not understood on what basis Paramādīśvara has called Lalla as Āryabhaṭa's disciple. The above verses compiled by Lalla himself show that he has nowhere called himself as Āryabhaṭa's disciple. On the contrary from the words in those verses it appears that he was not Āryabhaṭa's disciple.

From this, Śaka 420 does not seem to be his date. He must have lived many years after Āryabhaṭa.

Lalla has given 359° as the longitude of the junction-star of Revatī. The time for the junction-star of Revatī to cover one degree to the West of the initial point, according to Lalla tantra (that is, from the point occupied by the sun at the moment of the actual Aries Ingress) comes to about Śaka 600. But it has been shown above that Brahmagupta knew nothing about Lalla's work ; Lalla's works describe all instruments except the '*turīya*' (*quadrant*) *instrument* described by Brahmagupta. It shows that Brahmagupta's work was not known to Lalla. This leads one to surmise that both were contemporaries, but residing at distant places.

Śrīpati has compiled his work '*Ratnamālā*' with the help of Lalla's, 'Ratnakośa'. Śrīpati's date is Śaka 961. Lalla must have lived long before this date.

His work does not discuss the question of the precession of equinoxes. This shows that he must have lived about the time of Brahmagupta.

From all these considerations, the author thinks that Lalla's date might be a time near about Śaka 560.

His Ability

It is true that Bhāskarācārya has criticised Lalla, the author of "Dhīvṛddhida", but he states in the 20th verse above, that he has determined these corrections already mentioned, after ensuring agreement with the observed positions himself. This shows that he used to take observations himself and was a researcher ; and this fact was very creditable to him. The corrections given to Mercury and other planets show that the need to find them out must have arisen after a period of time had elapsed after Āryabhaṭa. It has already been mentioned that the Karaṇa works 'Karaṇaprakāśa' (Śaka 1014) and 'Bhaṭatulya' (Śaka 1339) were compiled after applying Lalla's corrections to the planets calculated according to the Siddhānta of Āryabhaṭa I.

PADMANĀBHA

Bhāskarācārya refers in his algebra to this name as a writer on algebra Colebrooke* has observed that he appears to have lived before Śrīdhara, as can be seen from Śrīdhara's work described below. Hence Padmanābha's date, as compared with that of Śrīdhara, does not appear to be later than Śaka 700.

Śrīdhara

Mahāvīra's work described below shows that a writer named Śrīdhara lived before him and that he wrote a work on 'vyāktagaṇita' (arithmetic), similar to that of Bhāskarācārya's Līlāvatī. Colebrooke had obtained the book, 'Gaṇitisāra', by Śrīdhara. It contained the subjects of arithmetic and mensurationo It shows, that this person Śrīdhara and the one referred to by Mahāvīra in his work, must be the same person, and Śrīdhara's date, as determined from that of Mahāvīra does not appear to be later than Śaka 775. Śrīdhara, mentioned by Bhāskarācārya as the author of algebra, seems to be this very person.

MAHĀVĪRA

He has written 'Sārasaṃgraha' a work on 'vyāktagaṇita' which deals with arithmetic and mensuration. An incomplete copy of the work came to notice in the collection of books belonging to late Dr. Bhau Daji. The description given in its beginning shows that Mahāvīra was a Jain by religion and that he had the patronage of the Jain King Amoghavarṣa. This shows that he lived in the reign of Amoghavarṣa I, the Jain king of the Rāṣṭrakūṭa dynasty, that is, about Śaka 775.

His work 'Sārasaṃgraha' resembles Līlāvatī of Bhāskarācārya but is more extensive and consists of at least 2000 "granths" (or verses in Anuṣṭup metre).

The Sārasaṃgraha contains some lines from Miśrakavyavahāra' (miscellaneous subjects) from the work of Śrīdharācārya, mentioned above.

ĀRYABHAṬA II (ABOUT ŚAKA 875)

His Work

There is another Ārya Siddhānta in addition to the siddhānta of Āryabhaṭa described before. There is a copy of the work, kept in the Deccan College

*Colebrooke's Miscellaneous Essays pp. 442, 450, 470.

Collection, but it is entitled as Laghu-Ārya Siddhānta. But the author himself calls it neither 'bṛhat' (extensive) nor 'laghu' (short). In the very first verse he observes.

विविधखगागमपाटीकुट्टकबीजादिदृष्टशास्त्रेण ।।

आर्यभटेन क्रियते सिद्धांतो रुचिर आर्याभि ।। १ ।।

"This beautiful Siddhānta has been compiled in the 'Ārya' metre by Āryabhaṭa who has studied various sciences on planetary motions, elementary mathematics, problems in arithmetic, and algebra".

In this, he calls his work a Siddhānta. This author is more modern than the earlier Āryabhaṭa and I have called him as Āryabhaṭa II and his work, Second Ārya Siddhānta, because it is convenient to do so.

His Date

He has not mentioned his date. He has given in his Siddhānta the mean places mentioned by another Siddhānta known as Parāśara Siddhānta. He describes both these siddhāntas,

एतत्सिद्धांतद्वयमीषद्यांते कलौ युगे जातं ।। २ ।।   अध्याय २,

meaning "compiled when a small part of Kaliyuga had elapsed". In this verse he intends to show to the world that the two Siddhāntas were compiled very soon after the Kaliyuga had started. But I am quite sure that he lived after Brahmagupta, because, even though he maintains that his Siddhānta was compiled very soon after the beginning of Kaliyuga, he includes himself among the authors of "pauruṣa" (human) works. There is no other proof to show that the length of year or other measures adopted by him were in use before Brahmagupta, and all criticisms levelled by the latter against Āryabhaṭa apply to the First Ārya Siddhānta and not at all to this. No subject dealt with in this Siddhānta has been referred to by Brahmagupta. Had this Siddhānta existed in his time, Brahmagupta would not have failed to criticise it in some respect or the other. The Pañcasiddhāntikā does not appear to have mentioned the equinoctial motion. It is not found in the works of Āryabhaṭa I, Brahmagupta or Lalla. But it is given in this Ārya Siddhānta and the authors appear to have attempted to remove the blemishes for which Brahmagupta has criticised Āryabhaṭa I. His work describes the Yuga-system, and the Kalpa begins on Sunday and Brahmagupta has criticised Āryabhaṭa I that his work recommends the planetary calculation, from the beginning of the Yuga when only the 'mean planets' are said to come together and not the 'true planets'. (see 46th couplet, Chap. 2). But according to this Āryabhaṭa's work, the true positions of all planets are given to be together at the beginning of Creation. All these facts have convinced the author that he lived after Brahmagupta *i.e.* after Śaka 587. This is the farthest limit of his date. As regards the nearest limit,' Bhāskarācārya has quoted him (in his work). In the 65th verse of the chapter on true places, in Siddhānta Śiromaṇi, he observes "Āryabhaṭa and others have mentioned the rising of the 'dṛkkāṇa' *i.e.* the third part of a sign or 10°, to ensure accuracy". Āryabhaṭa I has mentioned the duration of ascendants in terms of arcs of 30° and not of 10° ; but Āryabhaṭa II has mentioned the durations for the ascension of 'dṛkkāṇas' that is arcs of 10° ; in couplets 38 to 40 in the 4th chapter, and such a mention of the duration of 'dṛkkāṇa' is not at present found in any work except in that of Āryabhaṭa II. This shows that Āryabhaṭa referred to by

Bhāskarācārya in the above line is not the first Āryabhaṭa, but the second. from this it is clear that Āryabhaṭa II must have lived before Śaka 1072. He has described the method of calculating ayanāṃśa ; but the equinoctial motion as calculated from it is not found always to be constant, but to increase or decrease much (more discussion about this will be made in the study of the motion of equinoxes). But there is no harm in saying that the equinoctial motion is always constant ; the variation in it is exceedingly small. The modern Sūrya Siddhānta gives a constant motion for it ; but the date of its compilation is not definitely known. The work, Rājamṛgāṅka (Śaka 964) has adopted a constant motion for the equinox for all times. No definite proof of the measures adopted (by) earlier (writers) is at present available. From this, Āryabhaṭa II appears to have lived before the equinoctial motion was correctly known. The Bhaṭotpala's commentary (Śaka 888) quotes from several works, but not from the second Ārya Siddhānta. It shows that even if Āryabhaṭa II lived before Bhaṭotpala, he must have preceded him only by a few years.

The time when the ayanāṃśas, obtained from the Second Ārya Siddhānta, would be equal to the sun's tropical longitude at the true vernal equinox, comes to be about Śaka 900. If he had lived before this year, the date must have been only a few years earlier.

From all these considerations, he seems to have lived about the Śaka 875. It has already been shown before (page 33) that the date of his Siddhānta and that of Parāśara, as found by Bentley, are incorrect.

Description of his Work

His work consists of 18 chapters, which contain 625 couplets. The first 13 chapters deal with all the subjects usually discussed in different chapters in karaṇa works. The 14th chapter deals with the celestial sphere and problems concerning it. The 15th chapter consisting of 120 couplets is devoted to Pāṭīgaṇita (i.e. arithmetic and mensuration) ; and it contains almost all the questions dealt with in Bhāskarācārya's Līlāvatī. The 16th chapter is devoted to bhuvanakośa (Universe) i.e. the description of the three worlds. The 17th Chapter gives a theory of the mean motions of Planets, and the 18th chapter deals with algebra, and particulary the 'kuttaka' problems in it. It gives some special information not given by Brahmagupta.

Numerical Code

He has adopted the usual conventional code to denote numbers in 'Pāṭīgaṇita' (i.e. arithmetic and mensuration) only ; otherwise he has used, everywhere else, the letters of the alphabet to denote numbers. These letter values are different from those used by Āryabhaṭa I. They are :—

Consonants	Numbers denoted	Consonants	Numbers denoted
Ka, ṭa, pa, ya	1	ca, ta, ṣa	6
kha, ṭha, pha, ra,	2	cha, tha, sa	7
ga, ḍa, ba, la,	3	ja, da, ha,	8
gha, ḍha, bha, ba,	4	jha, dha,	9
ṅa, ṇa, ma, śa	5	ña, na,	0

While denoting numbers by letters, Āryabhaṭa I has not abandoned the general rule that', "digits are written from right to left" but this Āryabhaṭa has differed from it, and has adopted the system of writing the digits from left to right. Example : According to this system the word 'ghaḍapha' denotes 432.

It has been pointed out in the account of Āryabhaṭa I how confusion is caused by adopting his system of code letters. The same remark applies to this Āryabhaṭa also.

Below are given the numbers of revolutions and other elements etc. in one Kalpa as given by his Siddhhānta as well as by that of Parāśara.

	Second Ārya Siddhānta	Parāśara Siddhānta
Years spent over creation	3024000 In one Kalpa	0 In one Kalpa
Revol. of stars	1582237542000	1582237570000
Revol. of Sun	4320000000	4320000000
Sāvana days	1577917542000	1577917570000
Moon's revolutions	57753334000	57753334515
Moon's apogee : revolutions	488108674	488104634
Moon's node : revolutions	232313354	232313235
Mars	2296831000	2296833037
Mercury	17937054671	17937055474
Jupiter	364221682	364219955
Venus	7022371432	7022372148
Saturn	146569000	146571813
Solar months	51840000000	51840000000
Intercalary months	1593334000	1593334515
Lunar months	53433334000	53433334515
Tithis	1603000020000	1603000035450
Suppressed days	25082478000	25082465450

Planets	Revolutions of apsides in a Kalpa		Revolutions of nodes in a Kalpa	
	Second Ārya Siddhānta	Parāśara Siddhānta	Second Ārya Siddhānta	Parāśara Siddhānta
Sun	461	480		
Mars	299	327	298	245
Mercury	339	356	524	648
Jupiter	830	982	96	190
Venus	654	526	947	893
Saturn	76	54	620	630

Length of year, according to Ārya Siddhānta.—365^{d}—15^{gh}—31^{pal}—17^{vip}—6^{pvp}
Length of year, according to Parāśara Siddhānta—365—15—31—18—30.

According to Ārya Siddhānta it is assumed that some years have been spent over creation. No such assumption has been made in Parāśara Siddhānta. According to both the Siddhāntas the planets appear to come together not in the beginning of Kaliyuga, but at the beginning of Creation. The length of the year according to both is nearly equal to that of the rectified Brahma Siddhānta. This Āryabhaṭa has mentioned the number of revolutions of the "saptarṣi" stars (Great Bear), on the assumption that they have some motion. But as a matter of fact the Saptarṣis have, practically, no motion.

Parāśara Siddhānta

He remarks about Parāśara as follows :—

पाराशर्या दिविचरयोगे नेच्छंति दृष्टिफलं ।। १ ।।

अध्याय ११

"The followers of Parāśara Siddhānta do not accept any 'phala' *i.e.*, result for the mutual aspects of planets";

and after passing the remark,

कलिसंज्ञे युगपादे पाराशर्यं मतं प्रशस्तमतः ।। वक्ष्ये तदहं...... ।। १ ।।

अध्याय १

meaning "I describe here Parāśara's view since it is the best in Kaliyuga", he has mentioned its elements. From this, the Parāśara Siddhānta appears to be an independant work; but it is not available at present.

BALABHADRA

The commentary on Brahma Siddhānta by Pṛthūdaka, cites Balabhadra's name several times and has given a number of verses in "anuṣṭup" metre in his name. Those verses quote, in versified form, the elements given in the Brahma-Siddhānta itself. Even Bhaṭotpala's commentary on the Bṛhat Saṃhitā quotes some verses and Ārya couplets in the name of Balabhadra. They relate to the section on mathematics ; they have, however, no connection with the Brahma Siddhānta. This shows that he may have compiled an independent work on planetary calculation. The lines which have been given by Pṛthūdaka as quoted from Balabhadra may have been from his commentary on the Brahma Siddhānta. The author thinks that it might have been customary in ancient days to have at least a part of the commentary in verse form, when the text itself was in verse form. That Paramādīśara has quoted in his commentary on Āryabhaṭīya, some verses from his commentary on Līlāvatī would serve as an instance in point. In case Balabhadra had written an independent work, it is not now available. His date is clearly earlier than that of Bhaṭotpala, that is Śaka 888.

BHAṬOTPALA

His Date

He was a great commentator. He has stated the date of the compilation of his commentary on Bṛhajjātaka in these lines.

चैत्रमासस्य पंचम्यां सितायां गुरुवासरे ।। वस्वष्टाष्ट ८८८ मिते शाके कृतेयं विवृतिर्मया ।।

meaning, "I wrote this commentary on Thursday, the 5th lunar day of the bright half of Caitra in Śaka 888", and that of the commentary on Bṛhatsaṃhitā in the verse.

फाल्गुनस्य द्वितीयायामसितायां गुरोर्दिने ।। वस्वष्टाष्ट ८८८ मित शाके कृतेयं विवृतिर्मया ।।

meaning "I wrote this commentary on Thursday, the 2nd lunar day of the dark half of Phālguna in Śaka 888."

If Śaka 888 be regarded as an 'elapsed' year, the second lunar day of the dark half of either amānta Māgha or Phālguna is not found to fall on Thursday. The 2nd lunar day of the bright half of Phālguna was a Thursday. A Thursday is found to fall on the 2nd lunar day of the dark half of (Amānta) Māgha in Śaka 887, but not on the 2nd lunar day of either the bright or dark half of Phālguna. This shows that the Śaka year 888 referred to in the second verse must be the "current" year, equivalent to Śaka 887 elapsed ; and the Phālguna may be the month belonging to the 'pūrṇimānta' system ; that is, it must be the amānta Māgha.

But the 5th lunar day of the bright half of Caitra does not fall on Thursday either in Śaka 888 or in 887. In Śaka 887, the day happens to be Friday and in Śaka 888, it was a Wednesday. It appears that there must be some error in this ; and so long as it is not detected, the Śaka 888 mentioned in the verse cannot definitely be said to be a 'current' year. In any case, there is no doubt that the year must be one of the two Śakas, 888 or 887.

Commentaries

Utpala has written a commentary on Khaṇḍakhādya, but its Śaka is not known. However, in the commentary on the 5th chapter of Bṛhatsaṃhitā, one

comes across the remark "khaṇḍakhādyakaraṇe asmadīya vacanam", meaning "as I have stated in the commentary on Khaṇḍakhādya". It, therefore, shows that he wrote the commentary on Khaṇḍakhādya before this. Similarly, a reference made by him in his commentary, on Bṛhatsaṃhitā (Chap. 44) shows that his commentary on Varāha's travel was written before that on Bṛhatsaṃhitā. He has written a commentary on Laghujātaka also. He has, thus written commentaries on the following works compiled by Varāha—Yātrā, Bṛhajjātaka, Laghujātaka, and Bṛhatsaṃhitā, and a commentary on Brahmagupta's Khaṇḍa-Khādya. The commentary on 'yātrā' (travel) is not now available. Those on Bṛhajjātaka, Laghujātaka and Bṛhatsaṃhitā are available in this province, and of them, the first two have been printed.

Place

The commentary on Khaṇḍakhādya, written on the bark of the birch tree which is now in the Deccan College Collection, was originally found in Kashmi. The author does not think this commentary is available in other provinces That this commentary was well known in Kashmir can be seen from another commentary on Khaṇḍakhādya written in Śaka 1564 and from the Pañcāṅga Kautuka written in Śaka 1567, both written in Kashmir. It shows that Bhaṭotpala was a resident of Kashmir ; and Varuṇa, the commentator of Khaṇḍakhādya, clearly states that he was a resident of Kashmir

Independent Works

He seems to have compiled an independent work on the mathematical branch as can be seen from a couplet given by him at a place with the remark "as I have stated" in the first chapter of the commentary on the Bṛhatsaṃhitā. He might have taken the quotation from his commentary on Khaṇḍakhādya. Bhaṭotpala has compiled 'praśnajñyāna'. a work on 'praśna' (Questions), consisting of 72 āryā couplets.

Love of Research

It appears from the commentary on the Bṛhatsaṃhitā that Utpala was a keen researcher of ancient works and his reading was vast. He has written at several places that Varāhamihira had taken the help of ancient works on most of the questions on which he had written, and he (Utpala) has even cited the names of those works at some places. Utpala has also given quotations from the authors of ancient Saṃhitā works on those subjects at all or almost all such places. At some places are found quotations from as many as 8 to 10 authors of Saṃhita works. It is clear that all these saṃhitās were avialiable in his time. Similarly, he has given the quotations and names of several 'pauruṣa' (human) writers of works on Saṃhitā, Jātaka or some of the subsections of the subjects. Utpala's commentary on the Bṛhatsaṃhitā would be of great help in assessing the state of the knowledge of various subjects relating to the saṃhitā branch, and its growth in our country, and because of this and other reasons, the commentarly is worth publishing. The commentary is very extensive. The whole volume may be found to consist of about 14000* "granths" yerses and (the above two verses show that) this voluminous commentary was compiled by him in about eleven month's time, which is indeed a very remarkable feat. Utpala has writter a commentary on 'ṣatūpañcāśikā, a work on Jātaka by Pṛthuyaśa, son of Varāhamihira'a copy of which is kept in the Poona College Collection (No. 335 of 1882-83).

* The term "Grantha" in such context means verses in Anuṣṭup metre Consisting of 32 letters each.

about the same year. The commentary shows him to be a resident of a village named something like 'Cārayyāt' in the area 'Uruṣā' region, near Kashmir. The position of the place has been mentioned by him as latitude 34°22′ and longitude equal to 99 yojanas, east of Ujjayinī meridian (*i.e.* about $7\frac{1}{2}$° or 450 miles).

A surprising fact has been noticed in his commentary on Khaṇḍakhādya. At the very outset it has been remarked, in his commentary on the calculation of ahargaṇa ;

उक्तंच सिद्धांतशिरोमणौ । अभीष्टवारार्थमहर्गणश्चेत् सैको निरेकस्तिथयोपि तद्वत् ।।
तदाधिमासावमशेषके च कल्पाधिमासावमयुक्तहीने ।।*

Translation.—"So is said in the Siddhāntaśiromaṇi. If you are calculating ahargaṇa corresponding to a particular day of the week, you will have either to add 1 to or subtract 1 from the result. The same will have to be done in the case of particular tithis. Similarly while finding the 'adhimāsa śeṣa' or 'avama śeṣa' the number of intercalary and 'avama' days in a Kalpa undergoes a similar positive or negative change".

This verse is given by Bhāskarācārya in his Siddhāntaśiromaṇī and on the basis of this (verse) Varuṇa should be said to have lived after Śaka 1072 ; but several examples in his commentary show that his date comes to about Śaka 962 and there is absolutely no doubt about it. This verse clearly appears to have been interpolated by some one later on ; otherwise, who knows if there existed another work, named Siddhāntaśiromaṇi, compiled earlier than Śaka 962, which contained this verse word for word?

RĀJAMṚGĀṄKA

Date

This is a karaṇa work. It has adopted Śaka 964 as its epoch. The epochal positions have been given for the Sunrise (mean sunrise) i.e. for Sunday morning, the 13th cum 14th lunar day of the dark half of amānta Phālguna of Śaka 963.

Basis

That the work has been compiled after applying corrections to the planetary positions derived from the Brahma Siddhānta has nowhere been explicitly stated ; still, the epochal positions are found to agree with calculated figures when the corrections are applied to the planets according to the Brahma Siddhānta. The epochal positions are as follows :—

	S	°	′	″		S	°	′	″
Sun	10	28	45	0	Venus	6	7	52	39
Moon	10	9	2	53	Saturn	6	20	4	31
Mars	8	2	9	47	Moon's apogee	5	10	30	45
Mercury	8	1	33	15	Moon's node	2	16	58	5
Jupiter	3	1	0	30					

*There are two Versions of the book in the Deccan College Collection under Nos. 526 and 527 of 1875—76 A.D. This verse has been taken from the first of them.

The positions of apsides and nodes at the epoch of the Karaṇa work have also been taken from the Brahma Siddhānta. The correction suggested in it and the method of finding it is given in the following verse :—

नंदाद्रींद्वग्नि ३१७९ संयुक्तान् भजेत् खाभ्राभ्रभानु १२००० भिः ॥
शाकाब्दानविनष्टं तु भाजकाच्छेषमुत्सृजेत ॥ १७ ॥
तयोरल्पं द्विशत्या २०० तं बीजं लिप्तादिकं पृथक् ॥
त्रिभिः ३ शरैं ५ भुवा १ द्वयक्षै ५२ बाणै ५ स्तिथिभि १५ रब्धिभिः ४ ॥ १८ ॥
द्विकेन २ यमले २ नैवं गुण्यमर्कादिषु क्रमात् ॥ स्वं शशीघ्रे धरासूनौ सूर्यपुत्रेपरेष्वृणं ॥ १९ ।
मध्यमाधिकार

Translation.—Add 3179 to the Śaka year. Divide the sum by 12000. Subtract the remainder from the divisor itself (*i.e.* from 12000). Divide the smaller of the two (*viz* the remainder or 12000-remainder) by 200, and multiply it by 3,5,1,52,5,15,4,2 & 2, respectively in the case of the planets in order (*viz.* the Sun, the Moon, Mars, Mercury, Jupiter, Venus, Saturn, Moon's apogee, and Moon's node) so as to obtain the respective corrections. They are positive for Mercury, Mars and Saturn, and negative for others.

Author

—Chapter on mean places. The Colophon contains the following line :

इत्युर्वीपतिवृंदवंदितपदद्वंद्वेन सद्बुद्धिना ॥ श्रीभोजेन कृतं मृगांककरणं ज्योतिर्विदां प्रीतये ॥

Translation :—"This Karaṇa work, known as 'Mṛgāṅka', has been compiled with the good intention of satisfying the astronomers, by Śri Bhoja who is revered by rulers of the earth".

This shows that this Karaṇa was compiled by King Bhoja. The above—. mentioned correction is not found in any of the earlier works now availablle. It appears to have been devised at the time of Bhoja himself. It seems probable that he patronised some astronomers, got them to take observations for a number of years, and after comparing the observed places with those calculated from the Brahma Siddhānta, he finally determined the figures for correction so as to agree with other works also. It is not known if King Bhoja possessed the knowledge of astronomy as would be sufficient to compile a Karaṇa work himself. If not, the astronomers under his patronage may have compiled it and named it after him. But even if that be the case, there is no doubt that the astronomers had acquired the ability to compile a new work in the light of observations only on account of the royal patronage.

Subject Matter

This work contains only two chapters viz. one chapter on mean places and other on true places of planets and the two together contain 69 verses. It appears that they may be calculating eclipses directly with the help of the Siddhāntas. This work is not in use anywhere at present ; and because of the lapse of many years, the ahargaṇa calculated from it would be a very large number and hence very inconvenient for calculating the mean places ; because of this and also other Karaṇa works which have been compiled later, this work may naturally have gone out of use. Even then it appears to have been in use for a

Advantages

The mean planetary places used to be calculated from the ahargaṇa in well-known earlier Karaṇa works like the Pañca Siddhāntikā, Khaṇḍakhādya and Rājamṛgāṅka. In other words, they describe the method of calculating mean motions and mean places of planets from the number of days obtained by multiplying by 365¼ the number of years elapsed after (epoch of) the Karaṇa work. But the ahargaṇa increases with the increase in the number of years elapsed, and this causes lengthy multiplications and divisions. If tables showing mean motions for successive periods of days are prepared for calculating mean places, the calculation of mean places of planets would take very little time, or if mean places are found from the number of years elapsed after the epochal year, on the basis of the yearly mean motions of planets, even then it would take very little time. But it is surprising that the Pañcasiddhāntikā, Khaṇḍakhādya and Rājamṛgāṅka, and even well known Karaṇa works like the Karaṇa prakāśa, Karaṇakutūhala and Grahalāghava which were compiled after them, and from which calculations are made even now, give the extremely laborious method of finding mean places of planets from the total ahargaṇa. The mean place of a planet can be obtained from 'varṣagaṇa' or from tables in one tenth of time or even less required for finding the place by that method. The present work, Karaṇa Kamala Mārtaṇḍa, has not only given methods for finding planets' places from 'varṣagaṇa' but has also prepared tables of motions in period of years in order to save the labours of multiplying the 'varṣagaṇa' by the figures of annual motions. This is a great advantage. Some astronomers, who following the Grahalāghava, are, in these days, found using tables giving motions for days which are useful in finding planets positions from the ahargaṇa. Similar tables based on the Pañca Siddhāntikā and other works, might have been compiled by astronomers at different times ;but many ignorant astronomers are found who prefer the overlaborious method given in the old works instead of making use of tables, because these are not met with in the works. The author of Karaṇa-Kamala Mārtaṇḍa deserves praise in this respect. The work gives the calculation of mean places of planets from the mean Aries Ingress. It is somewhat surprising that the positions at the epoch and the yearly motions are not given in verse form; but it seems that these may have been given in the tables which accompany the work. The work seen by the author (Deccan College Collection No. 20 of 1870-71) however, contains tables for 'Tithi Śuddhi' only. The work, as it stands, is not sufficiently useful for making planetary calculation. It contains the following ten chapters consisting of 279 verses in 'anuṣṭup' metre:- mean places (of planets); three problems; lunar eclipse; solar eclipse; risings and settings; elevations of the moon's cusps; soli-lunar parallels of declinations; conjunctions of planets; true intercalary months; and calculation of the saṃvatsara (year). This work has assumed Śaka year 444 as the no-precession year and one minute of arc as the annual rate of precession.

The Aufrecht catalogue mentions another work by Daśabala, entitled *Cintāmaṇi Sāraṇikā* which contains tables useful for almanac-making. Daśabala claims that the work of almanac-making can be expedited to a great extent through the aid of his work. He also appears to claim that the like of his work was never compiled before

KARAṆA PRAKĀŚA

Date and Author

This is a Karaṇa work. The epoch of the work is Śaka 1014. The author, observes, in the beginning,

नत्वाहमार्यभटशास्त्रसमं करोमि श्रीब्रह्मदेवगणकः करणप्रकाशं ॥

Translation :—"I, the astronomer, Brahmadeva by name, most humbly compile this work, Karaṇa Prakāśa, in conformity with the 'Science' of Āryabhaṭa".

From this it is clear that, the astronomer, Brahmadeva, compiled this work following the (principles of) Āryabhaṭīya. The colophon of the work is as follows

आसीत्पार्थिववृन्दवंदितपदांभोजद्वयो माथुरा:
श्रीश्रीचंद्रबुधे गुणैकवसतिः ख्यातो द्विजेंद्रः क्षितौ ॥
नत्वा तस्य सुतोंघ्रिपंकजयुगं खंडेंदुचूडामणेः
वृत्तैः स्पष्टमिदं चकार करणं श्रीब्रह्मदेवः सुधीः ॥ ११ ॥

Translation :—"There lived a great Brāhmaṇa scholar, named Śrī Candra who was a (?) Māthura, reputed all over the world, who was the abode of virtues and whose feet were worshipped by a number of kings. His intelligent son, Brahmadeva, after worshipping the feet of Lord Śhiva, compiled this very accurate Karaṇa work in metrical form."

It appears from this that Candra was the name of Brahmadeva's father. Candra may have received the patronage of some king, or else as the above verse indicates, he must have been at least highly respected by some king. The name 'Māthura,' suggests that he may have been a resident of Māthura.

School

It is said in the beginning that this work was intended to be in conformity with the science of Āryabhaṭa and it is the first Āryabhaṭa who is thus referred to. Even then, the positions and motions of planets given in it agree with those obtained from the First Ārya Siddhānta only after Lalla's corrections are applied to the latter. This does not mention the corrections separately. The planetary positions and motions have been determined after taking into consideration those corrections. The epochal positions mentioned in it are true for the mean sunrise of Friday, the 1st lunar day of the bright half of Caitra of Śaka 1014.

They are :—

	s	°	'	"		s	°	'	"
Sun	11	16	32	57	Venus	10	11	28	58
Moon	11	27	20	20	Saturn	3	2	14	23
Mars	3	13	20	6	Moon's Apogee	1	5	49	16
Mercury	7	4	31	12	Moon's node	1	3	17	12
Jupiter	6	2	56	27					

These positions are found to agree, even to the seconds, with those obtained from the First Āryabhaṭīya after Lalla's corrections are applied to the latter.

met him in Śaka 1806. He knew the complete method of calculation based on Karaṇaprakāśa but he told the author that they did not always make their calculations from Karaṇaprakāśa. I actually did the calculations for the 'daśamī' referred to above, from Karaṇaprakāśa and obtained its duration ss 54^h—59^p after mean sunrise and 56 ghaṭis after true sunrise, for the longitude of Ujjayinī*. In short, the Karaṇaprakāśa is still in use to a certain extent. The author had to take a lot of trouble in procuring a copy of the work, and get one.

The Three Schools

It must be mentioned here that the tithi, according to Āryapakṣa, is found to be longer by 2 or 3 ghaṭis, only if Lalla's correction is applied to the calculations made from First Ārya Siddhānta otherwise not. Hence, it appears that a different criterion governing the observance of Ekādaśī, according to Āryapakṣa, might have been introduced, sometime after Lalla, for such criterion could not have existed before. There is a work on 'Muhūrta' (compiled in Śaka 1493) known as Muhūrta Mārtaṇḍa, which states that the tithi according to Āryapakṣa is longer than that according to Brahmapakṣa, by about four ghaṭis. This work and the Grahalāghava show that, in the 15th Century of Śaka era, the differences of the three schools (Ārya, Brahma and Saura) had become acute and each had its own circle of followers. Karaṇa Kutuhala and Rājamṛgāṅka are works following the Brahmapakṣa. Khaṇḍakhādya can be said to belong to the Saurapakṣa. No independent work compiled prior to Śaka 1014 following the Āryapakṣa, is available. Hence, the three schools appear to have become clearly divergent from Śaka 1000 or perhaps even from Lalla's time, and their followers might have begun to take pride in their respective creed.

The positions of planets mentioned in Grahalāghava as belonging to Āryapakṣa have been calculated from the Karaṇaprakāśa.

Bhāsvatī Karaṇa

Date, Author and place

This is a Karaṇa work. It has adopted Śaka 1021 as the epochal year. It has been compiled by an astronomer named Śatānanda. Aniruddha, the commentator of Bhāsvatī Karaṇa, says that Śatānanda was a resident of Puruśottamapurī that is Jagannāthapurī, and that the epochal positions given by him are true for that place. The convention generally followed is that the epochal positions are given as for Ujjayinī, irrespective of the place where the siddhānta works are compiled. But the author of Bhāsvatīkaraṇa appears to have departed from the convention, since Jagannāthapurī happens to be far away from the meridian of Ujjayinī and he was right. Śatānanda has, in the beginning, observed, "natvā Murāreścarṇāravindam" meaning, "after saluting

*Even four hour's labour will not be sufficient to calculate figures for Ekdāśī with the help of Karaṇaprakāśa. The author has done the calculation in about three quarters of an hour by another method which is easier than that and still gives results in conformity with the Karaṇaprakāśa.

the feet of Murārī (Lord Kṛṣṇa). From this, Mādhava, one of his commentators, says that he was a Vaiṣṇava. "Śatānanda observes in the first Adhikāra-

अथ प्रवक्ष्ये मिहिरोपदेशात् तत्सूर्यसिद्धान्तसमं समासात् ॥ ३ ॥

Translation.—"Now by favour of God Mihira, I compile a brief work equal to the Sūrya Siddhānta in merit".

Basis

Mādhava, one of the commentators of his Bhāsvatīkaraṇa interprets the word "Mihira" as the sun, and interprets the words "like his Siddhānta" as "from the Sūrya Siddhānta", and he has attempted to explain the positions and motions of planets in it with the help of the modern Sūrya Siddhānta, but he has failed in this attempt. He is everywhere required to justify his stand by remarking that "the Ācārya has ignored the slight differences." Mādhava has not at all understood the fact that Śatānanda compiled this Karaṇa work with the help of the Sūrya Siddhānta of Varāha's Pañca Siddhāntikā. The Pañca Siddhāntikā appears to have gone quite out of vogue in his time (Śaka 1442) and this may have been the reason for misunderstanding. The author has seen many other commentaries on Bhāsvatī but they do not explain the basis of the 'Kṣepaka'.

The epochal positions given by the Bhāsvatī are those, true for the moment of true Aries Ingress of Thursday, the New Moon day of the 'amānta' Caitra of Śaka 1021. The author could not exactly find for what moment on that day they are true, and hence, he could not verify if they agree upto minutes and seconds of longitude. However, the epochal positions are definitely true for the day of the true Aries Ingress and they agree,* for the most part with the figures obtained after applying the corrections (given on page 78) to mean places calculated from the Sūrya Siddhānta, given in the *Pañca Sidahāntikā* of Varāha. From this it is proved beyond doubt that the planetary positions cited cy Bhāsvatī are those obtained by applying the Varāha's corrections to the places derived from the original Sūrya Siddhānta. The annual motiors of planets are also given in the same way.

True Aries Ingress

The calculation of mean places, according to this work, is based, not on ahargaṇa but on 'varṣagaṇa' (*i.e.* the number of years elapsed), and it has already been pointed in the discussion on Kamalāmārtaṇḍa (page 107) that this method is very convenient. All other Karaṇa works which advocate the calculation of mean places from 'varṣagaṇa' start with the moment of mean Aries Ingress ; but this work starts with the moment of the true Aries Ingress. In preparing his plenetary tables Keropant has based the calculation of the planet's places on the true Aries Ingress.

Centisimal System

Śatānanda's work has one more speciality, viz. that he has adopted a centi-

---

*The ahargaṇa for verifying the epochal position given in Bhāswatī as calculated from (the epoch of) Pañca Siddhāntikā comes to 216962. One can easily see how labrious it would be to do the multiplication and divisions with this figure. If on the other hand the work had given the rates of annual motion, the basic figure would have been (1021—427)=594 and the planetary calculation would have been far more easy.

-simal system, for starting the epochal positions and the multipliers and divisors required in the calculation of the motions of planets. Ir doing so he has mentioned the positions and motions of the Sun and the Moor in terms of Nakṣatras and those for Mars and other planets in terms of Rāśis (Signs). The author quotes two examples of this. The rate of annual motion of the moon has been given as $995\frac{5}{6}$—. These are centisimal parts. This number, divided by 100, would give the required number of Nakṣatras. This would give

$$\frac{995\frac{5}{6}\times 800}{100}=7966\tfrac{2}{3} \text{ minutes}=4^s12^\circ46'40.''$$

The adoption of the motion in centisimal units such as $995\frac{5}{6}$ involves much less labour than that involved in adopting the motion in terms of signs, degrees, etc. Another example. The epochal position of Saturn is given as 594. This is given in terms of signs. The figure 594 when interpreted as so many centisimal units would give

$$\frac{594}{100}=5^s28^\circ12'$$

This system is somewhat similar to the present decimal system. One cannot say if the author of this Karaṇa work adopted the name Śatānanda because he loved the Śatāṃśa (centisimal) system.

Contents

The Bhāswati consists of the following eight *Adhikāras* (chapters)—(i) 'tithi dhruva' (ii) 'grahadhruva' (iii) true tithi (iv) true places of planets (v) three problems (vi) lunar eclipse (vii) solar eclipse and (viii) graphs. These consist of about 60 verses in all in different metres.

Bhāsvati has assumed Śaka 450 as the zero precession year, and 1′ as the annual rate of precession.

Commentaries

There is a commertary on Bhāsvati written in Śaka 1417 by Aniruddha of Vārānasī from which it appears that there were many other commentaries on it written before. Mādhava's commentary was written about Śaka 1442. He was a resident of Kanauj, (Kānyakubja). Another commentary was written by Gaṅgādhara in Śaka 1607. There is yet another commentary dated about Śaka 1577. Colebrooke says that Balabhadra's commentary was written in Śaka 1330. From the catalogue* of Sanskrit books prepared by Aufrecht, the title of this commentary appears to be Bālabodhinī. According to Aufrecht's Catalogue there are following additional commentaries on Bhāsvatikaraṇa :—Bhāsvatīkaraṇapaddhati ; Tatvaprakāśikā by Rāmakṛṣṇa ; Bhāsvatīcakraraśmyudāharaṇa by Rāmakṛṣṇa ; Udāharaṇa by Śatānanda ; Udāharaṇa by Vṛndāvana. Similarly, there are commentaries by Acyutabhaṭṭa, Gopāla, Cakravipradāsa, Rāmeśwara, Sadānanda and a "prākrit" commentary by Vanamāli.

Most of these commentators hail from Northern India. It shows that Bhasvatīkaraṇa was well known on that side. It is not at present known there, nor did I come across a reference to it in any other work.

KARAṆOTTAMA

Date

This Karaṇa work has been mentioned at several places by Mahādeo in his commentary on Śrīpati Ratnamālā. Mahādev quotes from this Karaṇa on

*The German Oriental Society has published at Leipzig in the year 1891, a very big extensive catalogue of Sanskrit books (Catalogus Catalogorum) prepared by a Germano scholar. Theodor Aufrecht, on the basis of 56 long lists of Sanskrit books, 19 of which Contained particulars of books at different places in Europe and 37 of those available in India.

precession. "Śaka vasutryambara candra hinaḥ", which means, "Śaka diminished by 1038". Similarly, he quotes also the following lines from it :— (i) "kalā rūpā yātāḥ karaṇaśaradaḥ sa śatayutā" and (ii) "Karaṇottamādau cāpyāyanāṃśā daśasamkhyāḥ", meaning (i) The precession in Kalās (minutes) is 600, equal to the years elapsed before the date of (compilation of) the Karaṇa and (ii) the ayanāṃśas adopted by the Karaṇottama at its beginning are 'ten'. This clearly shows that the work, Karaṇottama, was compiled in Śaka 1038. That Śaka 438 was taken to be zero precession year, and that the annual rate of precession was 1'. A statement from the Tājakasāra (Śaka 1445) viz that the places of planets should be calculated from Sūryatulya, Karaṇottama or Rāja Mṛgāṅka has already been given on page 41. Out of those Sūryatuly a might have been a work following the Saurapakṣa ;Rājamṛgāṅka has alreadey been shown to belong to Brahmapakṣa. Hence, it seems that the third, Karaṇottama, probably belonged to Āryapakṣa ; that it was in use in Śaka 1445, is obvious from the Śaka year of Tājakasāra. I have not read or heard of the work being available in use anywhere at present.

MAHEŚVARA

He was the father of Bhāskarācārya, the famous astronomer and author of Siddhānta Śiromaṇi. His date of birth may be about the year Śaka 1000 and his works may have been written about the year 1030 to 1040. The account of his ancestry will be found later in the account of Bhāskarācārya. According to the inscription of Ananta Deva, his great grandson, he compiled "Śekhara" a Karaṇa work, Laghujātakaṭikā, a work on astrology, and the work entitled Pratiṣṭhā vidhidīpaka (see account of Bhāskarācārya). Vṛttaśata is another work written by him. It may be identical with the Muhūrta work named Vṛttaśata.

ABHILAṢITĀRTHA CINTĀMAṆI

THE AUTHOR

King Someśwara III of the Uttara Cālukya dynasty, who was otherwise known as Bhulokamalla or Sarvajñya Bhupāla, compiled the work "Abhilaṣitārtha Cintāmaṇi or Mānasollāsa. It contains a number of subjects of which astronomy is one. The work has adopted Śaka 1051 as the epoch for planetary calculation. The following lines are found written with reference to it :—

एकपंचाशदधिके सहस्रे १०५१ शरदां गते । शकस्य सोमभूपाले सति चालुक्यमंडने ॥
समुद्ररसनामुर्वी शासति क्षतविद्विषि । सर्वशास्त्रार्थसर्वस्वप्रायोधिकलशोद्भवे ॥
सोम्यसंवत्सरे चैत्रमासादौ शुक्रवासरे । परिशोधितसिद्धांतलब्धाः स्युर्ध्रुवका इमे ॥*

Translation :—

It appears from this that the work has given epochal positions for Friday, the first lunar day of the bright half of Caitra of the above Śaka year, and the places of planets have been calculated from the ahargaṇa. As the author has not actually seen the work, it is not known from what Siddhānta-work the planet's places have been calculated.

*See Prof. Bhandarkar's *History of the Decoan*,(English) Journal of the Royal Asiatic Society, New Service.

OTHER WORKS AND AUTHORS BEFORE ŚAKA 1072

Bhāskarācārya's Siddhāntaśiromaṇi cites the names of a number of works, among which there are some which have not been described so far.

Mādhava's Siddhānta Cūḍāmaṇi has been referred to twice in Śiromaṇi (see pages 234 and 269 of Pandit Bāpūdeva's book). This Siddhānta is not now available.

Bhāskarācārya's 'Bījagaṇita' (algebra) refers to Brahmā and Viṣṇu Daivajña as writers on algebra who lived before him. Their works are not available at present. Of them, Brahmā may be the author of Karaṇaprakāśa.

BHĀSKARĀCĀRYA

He was a very famous astronomar. Not only is his fame resounding throughout our country for the last 700 years, but it has reached even the foreign countries. A brief account of his work will now be given.

He has the Siddhānta *Ś*iromaṇi and the Karaṇa Kutūhala, two astronomical works, to his credit. He writes in the Śiromaṇi.

HIS DATE

रसगुणपूर्णमही १०३६ समशकनृपसमयेऽभवन्ममोत्पत्तिः

रसगूण ३६ वर्षे मया सिद्वांतशिरोमणी रचित: ।। ५८ ।।

गोले प्रश्नाध्याये

Translation :—

"I was born in the Śaka year 1036 and I compiled the Siddhānta Śiromaṇi when I was 36 (58th verse)."

This shows that the year of his birth was Śaka 1036 and that he compiled Siddhānta Śiromaṇi when he was in his 36th year. The epoch adopted for the Karaṇakutūhala is Śaka 1105. From this, he appears to have compiled it in that year. He has himself written a commentary named Vāsanābhāṣya on two chapters of the Siddhānta Śiromaṇi, Grahagaṇita and Golādhyāya. At one place (in the chapter on the soli-lunār parallels of declination) in it he observes "I have similarly quoted the 'Śarakhaṇḍakas' in the karaṇa work" ; and he has, at some places in the commentary adopted 11° as the ayanāṃśa. This ayanāṃśa value of 11°, according to his view, was true in Śaka 1105. So he seems to have written the commentary about the Śaka year 1105. However, a part of the commentary may have been written before this and some portion may possibly have been written along with the original Siddhānta. He compiled the Karaṇa work in the 69th year of his age and a portion of the commentary also was written then. This speaks of his energy and intelligence at such a ripe age. Such people are very rare in our country at present. His works and other works also contain so much evidence about his date that there is absolutely no doubt about it.

ANCESTRY

Bhāskarācārya has recorded a brief history of his ancestors and has mentioned the place of his residence in the following verses :—

आसीत् सह्यकुलाचलाश्रितपुरे त्रैविद्यविद्वज्जने नानासज्जनधाम्नि विज्जडविडे शांडिल्यगोत्रो

द्विज: ।

श्रौतस्मार्तविचारसारचतुरो नि:शेषविद्यानिधि: साधूनामवधिर्महेश्वरकृती

दैवज्ञचूडामणि: ।। ६१ ।।

तज्जस्तच्चरणारविन्दयुगलप्राप्तप्रसाद: सुधीर्मुग्धोद्बोधकरं विदग्धगणकप्रीतिप्रदं प्रस्फुटम् ।

एतत् व्यवतसदुक्तियुक्तिवहुलं हेलावगम्यं विदां सिद्धांतग्रथन कुबुद्धिमथनं चक्रे

कवि र्भास्कर: ।। ६२ ।।

गोले प्रश्नाध्याय:

Translation :

(61) There was a Brāhmaṇa, Maheśvara by name, and belonging to Śāṇḍilya 'Gotra', who lived in the village of Vijjadavida, which was sheltered by the ranges of Sahyadri mountains, and which was inhabited by learned men well versed in the three Vedas. He was the formost among astrologers and best of virtuous persons, a treasure of all knowledge and shilled in the study of the Śruti and Smtṛi works.

(62) The poet Bhāskara, who was his son and worshiped his feet was very intelligent and he compiled a Siddhānta work which was aimed at being the enlightener of the ignorant and very much liked by the scholars, which was full of true and clear statements, accompanied by reasoning,which was easily intelligible to learned men and antidote to wrong thinking.

It is clear from this that his gotra was śāṇḍilya ; his father's name was Maheśvara from whom he got his learning. His place of residence was Bijjadavida, near the Sahyadri mountains.

There is a village named Pātan 10 miles S. W. of Ċalisgaon, in Khaṇḍeś ; at present it is a deserted place. In that village there is a stone inscription* in the Bhavāni's temple. Cangadeo, a grandson of Bhāskārācārya was an astronomer at the court of king Singhana of the Yādava dynasty. This Singhana (Simha) ruled at Devagiri from Śaka 1132 to 1159. Cangadeo built a *math* (monastery) at Pātan for the teaching works of Bhāskarācārya and those of his descendants. King Saideva of Nikhumbha dynasty, a feudal king of singhana made an endowment for the maintenance of this monastery in Śaka 1129

*The Late Bhau Daji discovered the inscription and published it in the journal of the R. A. So, N. S. Vol. I p. 414 ff. It was again printed well on p. 340 ff, Vol I, of *Epigraphia Indica*, and Pātan, the name of the village occurs in it.

and his brother, Hemadi, also made a grant. This information can be obtained from the above inscription. Cangdeva has drafted the contents of the inscription, a few years after Śaka 1128. The monastery does not exist now ; but one finds traces of its existence. This inscription gives an account of the forefathers and successors of Bhāskarācārya as follows :—

शांडिल्यवंशे कविचक्रवर्ती त्रिविक्रमोभूत् तनयोस्य जात: ।

यो भोजराजेन कृताभिधानो विद्यापतिर्भास्करभट्टनामा ।। १७ ।।

तस्माद्गोविन्दसर्वज्ञो जातो गोविन्दसंनिभ: । प्रभाकर: सुतस्तमात् प्रभाकर इवापर: ।। १८ ।।

तस्मान्मनोरथो जात: सतां पूर्णमनोरथ: । श्रीमानमहेश्वराचार्यस्ततोऽजनि कवीश्वर: ।। १९ ।।

तत्सूनु: कविवृन्दवन्दितपद: सद्वेदविद्यालता-

कंद: कंसरिपुप्रसादितपद: सर्वज्ञविद्यासद: ।

यच्छिष्यै: सह कोऽपि नो विवदितुं दक्षो विवादी क्वचि—

च्छ्रीमान भास्करकोविद: समभवत्सत्कीर्तिपुण्यान्वित: ।। २० ।।

लक्ष्मीधराख्योऽखिलसूरिमुख्यो वेदार्थवित् तार्किकचक्रवर्ती ।।

क्रतुक्रियाकांडविचारसारविशारदो भास्करनन्दनोऽभूत् ।। २१ ।।

सर्वशास्त्रार्थदक्षोऽयमिति मत्वा पुरादत: । जैत्रपालेन यो नति: कृतश्च विबुधाग्रणी: ।। २२ ।।

तष्मात् सुत: सिंघणचक्रवर्तिदैवज्ञवर्योऽजनि चङ्गदेव: ।

श्रीभास्कराचार्यनिबद्धशास्त्रविस्तारहेतो: कुरुते मटं य: ।। २३ ।।

भास्कररचितग्रन्था: सिद्धांतशिरोमणिप्रमुखा: ।।

तद्वंश्यकृताश्चान्ये व्याख्येया मन्मठे नियमात् ।। २४ ।।

Translation :—

(17) Trivikrama, the best of poets, was born in the Śāṇḍilya family. A son was born to him ; he was named Bhāskarabhaṭṭa and was made the 'Master of learning' by king Bhoja.

(18) From him was born a son Govinda, who resembled Govinda (Lord Kṛṣṇa), from whom was born a son, named Pravākara, who was another Prabhākara (Sun).

(19) From him was born Manoratha who was the fulfiller of "manorath's" (i.e. aspirations) of good men, and the great poet Maheśvara was born from him.

(20) His son, a scholar was so great and famous that his feet were worshipped by groups of scholars, he was the fruit borne by the creeper in the form of learning. he was the store of all knowledge, and he attained so much fame and

was so great that there could rarely be found any one on earth to debate even with his disciples.

(21) Lakşmidhara was the son of Bhāskara. He was at the helm of all learned men, who interpreted the Vedas and was the leader of logicians and was an expert in the science of 'mimānsā'.

(22) He being known to be well versed in all sciences was invited by king Jaitrapāla to his court, and was made the leader of all scholars.

(23) From him was born a son named Cangadeo, who was the senior most astrologer at the court of Emperor Singhana. He constructed a monastery with the intention of propagating Bhāskārācārya's works.

(24) All the works compiled by Bhāskara, the chief of which was the Siddhāntaśiromaṇi, and also the works compiled by his descendants, are to be regularly studied in my monsatery.

Bhāskarācārya's genealogical table, prepared on the basis of the above verses is given in the margin :—

Trivikrama
1
Bhāskara Bhaṭṭa
1
Govinda
1
Prabhākara
1
Manoratha
1
Maheśvara
1
Bhāskara
1
Lakşmidhara
1
Canga Deo

The gotra and the name of Bhāskara's father in this agree with those given by Bhāskarācārya himself. According to the inscription, the sixth person upwards from Bhāskarācārya in the table, was the tutor to king Bhoja Bhāskara, the author of Śiromaṇi, was born in Śaka 1036. Reckoning 20 years as the average for a generation, Bhāskara, the tutor of Bhoja, may be taken to have been born in Śaka 936. Hence it was not impossible for him to be the tutor of king Bhoja, the author of Rājamṛgāṅka, who lived in Śaka 964. The inscriptions further says that Lakşmidhara, the son of Bhāskara. the author of Śiromaṇi, was invited by king Jaitrapāla to his court and that his grandson, Cangadeo, was astronomer at the Court of Emperor Singhana. Jaitrapāla of Yādava dynasty ruled* at Devagiri from Śaka 1113 to 1132 and his son Singhana ruled from Śaka 1132 to 1169.

There is a village named Bahāl, 10 miles north of Calisgaon, in Khaṇḍeś, near the river Girana. There is an inscription in this villge in the temple of goddes Sārajā. According to this inscription, Maheśvara was the son of Manoratha, of Śāṇḍilya gotra ; his son was Śrīpati who had a son, named Gaṇapati. His son Anantadeo was the Head Astrologer at the Court of King Sinha (Singhana) of Yādava dynasty. In Śaka 1144, he built the above mentioned temple** of the goddess. It was he who got the inscription carved. This description of ancestry agrees quite well with that given in the Cangadeo's inscription. The first ancestor named in Cangadeo's inscription, is the author of the work, 'Damayanti Kathā'.

*See Prof. Bhandarkar's *History of the Deccan*, (English) p. 82.

**This inscription is reproduced on p. 112, Vol. III, *Epigraphia Indica*. The inscription states Dwārajā to be the name of the goddess.

THE PLACE OF RESIDENCE

Bhāskarācārya has not stated that he was patronised by any king, nor do we get such information in either of the two inscriptions. According to his statement, Vijjalaviḍa, was the place of his residence. The last two letters of this word suggest that Bīḍ might have been the place. But Bīḍ is a place in the Nizam state, 80 miles to the east of Ahmedanager. It is not situated near the Sahyadri ranges, and it is learnt from enquiry that there are no descendants of Bhāskarācārya living there at present. The Līlāvati of Bhāskara was translated in Persian, by Akbar's orders in 1587 A.D. (Śaka 1509). The translator has stated in it that the birth place of the author was Bidar in the Deccan. Bidar is a place about 100 miles to the east of Sholapur* in the Nizam State, but it is not near the Sahyadris. It is a place 30 miles to the east of the well known city of Kalyan. The kings of the cālukya dynasty were ruling at Kalyan at the time of Bhāskarācārya. Even though such a great kindgom existed so near, nothing is mentioned anywhere about the association of Bhāskarācārya with it. From this, we may conclude that Bidar was not Bhāskarācārya's place of residence.

It is stated in the 22nd verse of the Canga Deo's inscription that " king Jaitrapāla called Lakṣmidhara, son of Bhāskarācārya from the town, 'Pātan'. The village of Pātan is very near to Devagiri (Daulatabad), the capital of the Yādava Kings and it is near the Candwad hills which are off shoots of the Sahyadris ; that is, it is " sheltered by the Sahyadri range ", in the words of Bhāskarācārya. The village of Bahāl where Anant-Deo, a descendant of Bhāskara built the temple, is only about 20 miles from Pātan. This shows that Bhāskarācārya's original place of residence was, beyond doubt, the village Pātan itself or some village near it bearing some such name as Vijjalaviḍa. It is not known at present.

Subject matter of Siddhānta Śiromaṇi

The *Siddhānta Śiromaṇi* is divided into four main parts which are also called Chapters. Each part has a number of chapters in it. The first part is termed as the 'Pāṭigaṇita' or Līlāvati, by the author. This can be said to be an independent work on arithmetic and mensuration. It consists of about 278 verses. In between are also given explanations of examples in prose. In the beginning are given in it some tables of various measures ; next follow the terms for the places of digits in a number up to ' parārdha ' which is the 18th place. Next come the eight fundamental operations, addition, subtraction, multiplication, division, square and square root, and cube and cube root. They are termed ' parikarmāṣṭaka '. Then come subjects like, fundamental operations for fractions and those for zero, ' iṣṭakarma ' (unitary method), rule of three, rule of five, progressions etc. Similarly, these are followed by areas and volumes of different figures and solids. Next come subjects like " kuṭṭakagaṇit, pākṣika viparyaya and sarvāmśika viparyaya ", amongst which is given an example of special importance. " A peacock was sitting on a pole, 9 cubits in height. It saw a serpent at a distance of 27 cubits, approaching a hole at the foot of the pole. It jumped to catch the serpent. Both moved at the same speed. How far away from the pole will they meet? " The answer given is ' 12 cubits away from the pole '. This answer is correct if the peacock is supposed to have

*See Pott's Algebra (1886) Sec. II.

flown along the hypotenuse of the right angled triangle i.e. 15 cubits in a straight line. But it is worthnoting that the important mathematical idea that the path of a flying peacock would be a curve much different from the circumference of a circle which is not found in other Sanskrit works, had occurred to Bhāskarācārya. It is needless to say that such popular beliefs as that one can count the leaves of a tree by studying Līlāvatī, are baseless ; but they indicate people's reverence for the work. The second part of the work is known as ' bījagaṇita ' (Algebra). It contains the following subjects :— the addition etc. of positive and negative numbers, of unknown quantities and of surds. Then come the chapters on subjects like ' kuṭṭaka ' and ' varga-prakriti ', simple equations of one unknown quantity, simultaneous equations of more than one unknown and equations involving squares and higher powers of one or more unknown quantities. This consists of about 213 verses in all, with some prose portions in between.

The parts known as ' golādhyāya ' and ' gaṇitādhyāya ' are devoted to astronomy. The first part treats of all subjects related to planetary calculations which have been mentioned in the list of Adhikāra given in the Introduction. The number of verses in it, including those in the commentary, is stated to be 4346. The part known as ' golādhyāya ' deals with the theory of all questions discussed in the ' gaṇitādhyāya ', a description of the three worlds, a chapter on instruments of observation etc. The number of verses mentioned is 2100. In the end is given a very short but important chapter named " jyotpatti ". In the middle is given a short chapter entitled ' description of seasons' ; it has been compiled by Bhāskarācārya only to exhibit his poetic gift.

His Capability

Bhāskarācārya has adopted from the Brahmasiddhānta the numbers of revolutions and other elements of all planets given in the chapter on mean places and the degrees of epicycles in the chapter on true places. The corrections to be applied to mean positions of planets have been taken in toto from the work ' Rājamṛgāṅka '. Even the precessional motion has been taken from earlier works. In short, there is nothing new in Bhāskarācārya's works which is obtainable by observation ; but his work is full of knowledge obtainable only after deep study. This sort of knowledge is the origin of the theory of the Science of astronomy. The work Siddhāntaśiromaṇi has reached such a high degree of excellence on account of various simplified methods and the explanation of their underlying theory, covering all subjects from the trifling calculation of planets' places from ' ahargaṇa ' to abstruse questions like that of parallax and the sine theory, that we can really understand the essence of Indian astronomy by reading even this single work ; and it appears that it is on account of this Bhāskarācārya became so very famous. Several works of varying quality might have been thrown into the background because of this work. In view of the fact that even the Brahma Siddhānta which was revered by Bhāskarācārya like a preceptor, was surpassed by Bhāskara Siddhānta, one can easily guess how many other authors might have been consigned to oblivion because of Bhāskara's works. The period from Āryabhaṭa I to Bhāskarācārya is regarded as the most brilliant period so far as the development of Indian Astronomy is concerned. It is during this very period that the Khaliphs of Baghdad in their days of prosperity invited astronomers from India, got the Hindu works translated into Arabic and Latin, and the Arabs and Greeks became disciples of Hindus. It was in this very period that the problem of ' Ayana ' motion was fully studied. Several authors of works might have

flourished in this flourishing period of astronomy ; but some of them are now known only in name, while some others are not even so lucky. It is no doubt due to the march of time ; but it is felt at the same time that Bhāskarācārya was responsible for this to a great degree. No other author of equal calibre was born after him. Bhāskarācārya's works are well known in every nook and corner of the sub-continent of India. Not only this, but they have been, translated also even in foreign languages. But it is the misfortune of our country that such a genius failed to make any of the important discoveries made in Europe in modern times or even lay the foundation of at least one of them. Bhāskarācārya did not make any efforts in respect of observation. The author inclined to believe even from his meagre experience that if he had done it, his intelligence which was devoted to the task of merely explaining theories like a commentator would have definitely been diverted to new discoveries.

His works contain nothing new ; still, because he has devoted all his intellectual power to theory, his works do contain some new discoveries which are obtainable by study and not by observation. To him the knowledge of the sphere was at his fingure's ends. He has suggested a number of new methods in the chapter on three problems and has shown his ingenuity in dealing with several questions in them. Earlier astronomers had not described, in their study of the gnomon, the method of calculating the length of the shadow in any whatever direction but he alone has described it. He has remarked, " Earlier astronomers had been labouring under a delusion in respect of the calculation of the Mahāpāl (Soli-lunar parallel of declination); I described the correct method". Earlier astronomers appear to be regarding the arc of the latitude to be lying along the declination circle, that is perpendicular to the equator but he has clearly shown that latitude is perpendicular to the ecliptic. The correction known as ' udayantar ' is one of his discoveries. It is briefly described here :—

" When finding planets' places from the ahargaṇa, the days are all supposed to be of equal length ; but actually they are not so. Even at the equator, the days are somewhat longer or shorter than 60 ghaṭis (i.e. 24 hours) and this causes the difference between the moments of mean and true sunrise. The places of planets calculated from the ahargaṇa are true for mean sun rise. To deduce their places true for the true sunrise, earlier writers have prescribed the corrections known as ' bhujantar ' and ' cara '. Bhāskarācārya has prescribed one more correction known as ' udayantara '. The sun's motion in the ecliptic is not always uniform. The time of true sunrise differs from that of mean sunrise according to the equation of centre, that is, the difference between the true and mean longitude of the sun. The correction due to this is called ' Bhujantar '. The earth rotates round its axis : it rotates in the plane of the equator and not in that of the ecliptic. It is on account of this fact, that the 30° arc of the ecliptic does not always require the same time to come above the horizon as an equal arc of the equator. The correction necessary to cover this irregularity has been called 'Udayantara' by Bhāskarācārya and this correction is evidently necessary to be applied. The corrections of ' bhujantara ' and ' udayantara ' together are included into one term called " the equation of time " by the European astronomers. Thus Udayantara was one of the discoveries of Bhāskarācārya. Ranganātha, the commentator of the Sūrya Siddhānta has attempted to show in his commentary on the 59th chapter that this correction was desired by the author of the Sūrya Siddhānta and has remarked that the author had not mentioned it as it was very small. The author of the Siddhāntatatvaviveka has attempted to refute

Bhāskarācārya's argument about the need of the adoption of this correction of 'udayantara', but this attempt has proved futile as it shows sheer obstinacy. The Siddhānta-śiromaṇi discusses new trivial questions other than that of 'udayantara' and has in the discussion pointed out at two or three places, Brahmagupta's error".

Karaṇa Kutūhala

The Karaṇa work, Karaṇa-Kutūhala, has adopted Śaka 1105 as the epocha year. The moment of sunrise on Thursday, the new moon day of Phālguna of Śaka 1104, is the epoch for which the positions are given. The mean places have been calculated from ahargaṇa. Bhāskarācārya regards his work as comparable to Brahma Siddhānta, but as a matter of fact, it is so, only when the corrections recommended by Rājamṛgāṅka are applied. It is also called "Grahāgamakutūhala". It was very well known. Some persons use this for calculation even now. It has already been pointed out that the figures claimed by the author of the Grahalāghava, as belonging to Brahmapakṣa, have been taken from this work. There is a voluminous work called "Jagaccandrikāsāraṇi" containing tables which are used to calculate planets' places according to this work. The *Karaṇa Kutūhala* contains the following ten *Adhikāras* (chapters) (i) mean places (ii) true places (iii) three problems (iv) lunar eclipse (v) solar eclipse (vi) rising and setting (vii) elevation of moon's cusps (viii) conjunction of planets (ix) Mahāpāta (x) pūrvasambhava (possibility of eclipses). These respectively contain 17,23,17,24,10,15,5,7, 16 and 5 verses, making 139 verses in all.

Commentaries

No other astronomical work can boast of having so many commentaries on them as the works of Bhāskarācārya. Some of them deal with all the four sections of the Siddhāntaśiromaṇi. Some others are written on only the first part called Līlāvatī, some on only the second part known as 'Bījagaṇita' and still others deal with the two parts 'grahagaṇitādhyāya' and 'golādhyāya'. The commentaries on Līlāvatī are mentioned below :—

Gaṅgādhara, the son of Govardhana and a resident of Jambusara, has written a commentary called 'Gaṇitāmṛtasāgarī'; it probably belongs to Śaka 1342. This was also known as 'Aṅkāmṛtasāgarī', and the Aufrecht catalogue states that Lakṣmīdhara was another name of Gaṅgādhara. Gaṇeśa Daivajña, the author of Grahalāghava, wrote his commentary known as 'Buddhivilāsinī', in Śaka 1467. Dhaneśvara Daivajña has written a commentary called 'Līlāvatībhūṣaṇa'. Mahidāsa has written one in Śaka 1509. The commentary known as Līlāvatīvivṛtti has been written by Munīśvara in about the year 1557. The commentary by Mahīdhara, known as Līlāvatīvivaraṇa, refers to Munīśvara ; from this it appears to have been written after Śaka 1557. The Aufrecht Catalogue mentions the following additional commentaries :—

The '*Gaṇitāmṛta Laharī*' by Rāmakṛṣṇa, son of Nṛsiṃha, (1339 A.D.); the *Pāṭīgaṇita kaumudī*, a commentary by Nārāyaṇa, son of Nṛsiṃha (1357 A.D.). Manoranjanā by Rāmkṛṣṇadeo, son of Sadādeva; The *Līlāvatībhūṣaṇa* by Rāmacandra; *Nisṛṣṭadūtī* by Viśvarūpa ; *Gaṇitāmṛtakūpikā* by Śuryadāsa ; the *Udāharaṇa* by Candraśekhara Paṭanāyak ; Udāharaṇa by Viśveśwara and commentaries by Dāmodara, Devisahāya, Paraśurāma Rāmadatta, Lakṣminātha, Vṛndāvana, Śrīdhara-Maithila etc. Of these, the "Nisṛṣṭadūtī" commentary appears to belong to Munīśvara, because Viśvarūpa was another name of Munīśvara.

The commentaries on 'Bījagaṇita' :—The commentary known as Bījanavāṅkura by Kṛṣṇa, the famous astronomer at the court of Emperor Jāhāngir was written in about Śaka 1524. It is also known as Bījapallava and Kalpalatāvatāra. It is very extensive. There is a commentary known as Bījaprabodha written by Rāmakṛṣṇa, son of Lakṣmaṇa, who was the son of Nṛsiṃha Deo of Amraoti. This Rāmakṛṣṇa calls himself a disciple of Muniśvara. From this it appears that it belongs to about Śaka 1570. The Aufrecht catalogue mentions "Bījavivṛttikalpalatā" by Paramasukha, and '*Udāharaṇa*' by Kṛpārāma, as additional commentaries.

Gaṇeśa Daivajñya, author of the *Grahalāghava*, has written a commentary on "Grahagaṇitadhyāya and Golādhyāya". Gaṇeśa, the great grandson of Gaṇeśa Daivajñya, the author of the *Grahalāghava*, wrote a commentary known as 'Śiromaṇi Prakāśa, about Śaka 1500. The commentary known as Vāsanākalpalatā or Vāsanāvārtika by Nṛsiṃha, a resident of Golagrām, belongs to Śaka 1543. The Marīci commentary by Muniśvara or Viśvarupa is very extensive and the best one. It was written in Śaka 1557. Siddhāntasūryodaya, a commentary by Gopinātha, brother of Raghunātha and son of Bhairava, was written after Śaka 1450.

The following are the commentaries on the complete work of Siddhāntaśiromaṇi :—Sūryadāsa, son of Jñyānarāja, has written a commentary known as *Sūryaprakāśa* on all the four sections. The part of this commentary relating to Līlāvatī and Bīja was written in Śaka 1460. Paramādiśvara, the commentator of Āryabhaṭa I, is said to have written a commentary called Siddhāntadīpikā on the works of Bhāskarācārya. It appears to have been written on all the four sections. The commentary "Mitabhāṣiṇī", by Ranganātha, son of Nṛsiṃha, a resident of Golagrām, was written soon after Śaka 1580.

The Aufrecht Catalogue mentions the following additional commentaries :—The 'Gaṇitatatvacintāmaṇi by Lakṣmidāsa, son of Vācaspati (1501 A.D.) The Udāharaṇa, by Viśvanātha; and the commentaries by Rājagirīpravāsī Cakracuḍāmaṇi, Jayalakṣmaṇa or Jaya Lakṣmi, Maheśvara, Mohandāsa, Lakṣminātha, Vācaspatimitra (?) and Harihara. Most of them might be confined to Grahagaṇitadhyāya and Golādhyāya only.

The *Karaṇa Kutūhala*, has been commented upon by Soḍhala, by Padmanābha, son of Nārmada, and by Śaṅkar kavi. The last commentary has adopted Śaka 1541 as the year for its examples. There is a commentary dated Śaka 1482, which contains an example; the commentator was a resident of Unnata Durga. The place has 4-48 as the *palabhā* and 60 yojanas west, as *deśāntar* (longitude). The Aufrecht Catalogue mentions the following additional commentaries :—Gaṇitasār conforming to Brahmasiddhānta and written by Keśavārka; 'Gaṇakakumudakaumudī' by Harṣagaṇita; the Udāharaṇa by Viśvanātha, and the commentary by Ekanātha.

There may be* many more commentaries on Bhāskarācārya's works. The Līlāvatī was translated into Persian in Śaka 1509 and the Bīja in Śaka 1597. Colebrooke has published the English translation of Līlāvatī and Bījagaṇita in 1817 A.D. Paṇḍit Bāpudeva Śāstri published an English translation of Golādhyāya in the *Bibliotheca Indica* in 1861 A.D. The translation contains a number of notes. All parts of Śiromaṇi and the Karaṇakutūhala have been printed at several places in our country.

*The author has taken the information about some of the commentaries enumerated above from other books. He has not seen all the commentaries personally.

Mādhava (Śaka 1185) the commentator of Ratnamālā, and other writers have mentioned, 'Bhāskarvyawahāra,' a work on Muhūrta. It may be a work by Bhāskarācārya. A verse of Bhāskara has been quoted in connection with marriages in the commentary on Vivāhapaṭala by Rāma (Śaka 1446). A reference to the work Vivāhapaṭala by Bhāskara was also found in the 'Śārṅgīya' Vivāhapaṭala and in other one or two works ; and a small volume named Bhāskaravivāhapaṭala which is in the Deccan College collection, gives no information other than the author's name. It appears however, that Bhāskarācārya might have written a work entitled "*Vivāhapaṭala*".

Anantadeva

He was a descendant of Bhāskarācārya. His inscription at Bahāl dated Śaka 1144, has already been referred to above (page 117). He has mentioned in it that he wrote commentaries on "chandaścityuttara", the 20th Chapter of Brahmagupta's Siddhānta, and on Bṛhajjātaka.

ĀDITYAPRATĀP SIDDHĀNTA

The Mahādevī commentary on Śrīpati's Ratnamālā has quoted some lines from this Siddhānta. The Mahādevī commentary belongs to Śaka 1185. This Siddhānta must, therefore, have been written earlier than this. The Aufrecht Catalogue mentions it as written by Bhojarāja. If it be true, it belongs to about Śaka 964.

VĀVILĀLA KOCCANNĀ

A karaṇa work by Vāvilāla Koccannā, a Telanganā astronomer, belongs to Śaka 1220 ; and the epochal positions in it are given for the afternoon of Thursday, the New Moon day of Phālguna of Śaka 1219. I have calculated the planet's places from the modern Sūrya Siddhānta, and they agree with the author's places completely. It, therefore, clearly shows, that the work has been compiled with the help of the modern Sūrya Siddhānta. The work does not contain the correction to be applied to Sūrya Siddhānta according to Makaranda and other works. Mr. Warren, an European of Madras, compiled a work entitled 'Kāla Saṃkalita' in 1825 A.D. It incorporates the major part of this Karaṇa work and gives some information about it. It appears from this that the work is still in use in Telanganā, and almanacs are prepared with its help. These almanacs are known as "Siddhānta Cāndra-Pañcānga."

GRAHASIDDHI

It is a Karaṇa work. It is also known as Mahādevī Sāraṇī. It has adopted Śaka 1238 as the epochal year, and hence, it appears to have been compiled about that time.

Its History

The author, in the very beginning, observes,

चक्रेश्वरारब्धनभश्चराशुसिद्धिं महादेव ऋषींश्च नत्वा ॥ १ ॥

which shows that the work was first started by some astronomer, Cakreśvara, and then the imcomplete work was carried to completion by Mahādeva.

Dhanarāja wrote a commentary on it. Mahādeva has recorded his family history in the last 4 verses of the original work ; but the commentator has not commented upon them because the verses are very incorrect. There is a copy of the commentary in the Deccan College collection. The Ānandāśrama has got a copy of the work without a commentary (no. 2086) which contains the same verses in their incorrect form. One comes to know from it that Mahādeva was a Brāhmaṇa, his Gotra was Gautama. Padmanābha was his father's name and Mādhava* his grandfather's name. The Author has come across an old work named 'Jātakasāra', written in Sanskrit and, Gujerati. It has recommended the calculation of planets places from Mahādevisāraṇī. The copy of the Mahādevisāraṇī belonging to the Deccan College Collection was procured at Ahmedabad. The commentator also is the resident of a place near Gujerat, and Mahādeva himself has adopted 4½ as the 'palabhā' for calculating the ascensional difference (cara). It shows that he may have been the resident of a place near Surat in Gujerat, and it appears that the work might have been in use in Gujerat for a considerable period.

Contents

This work contains about 43 verses. They describe the methods of calculating only the mean and true places of planets. The epochal positions are given for the mean Aries Ingress and the work contains tables for calculating mean places of planets from 'varṣagaṇa', which simplifies all calculation. It has given the positions and motions of planets which are comparable to the Brahma Siddhānta, after the corrections mentioned by Rāja Mṛgāṅka are applied.

The Commentary

The commentator has given his account at the end. A portion of it is given below :—

वर्षेनेत्रनवांगभू १६९२ परिमिते ज्येष्टस्य पक्षे सिते-
ष्टम्यां सद्गुण पृथक्यमन्नरयु (?) पद्मावतीपत्तने ॥
राजाहुग्रत्करवैरिनागदमनो राठोडवंशोद्भवः
श्रीमान् श्रीगजसिंहभूपतिवरोस्ति श्रीमरोर्मंडले ॥
जैने शासन एवमंचलगणे...॥

Translation :—(There are omissions and inaccuracies in the text).

"In the village of Padmāvati, on the 8th lunar day of the bright half of Jyeṣṭha in Śaka 1692........"

"There is the King Gajasiṃha, of Rathoḍ family, who is a Jain and rules. ."

From this, the commentator appears to be a Jain. He has given Dhanarāja as his name. He has, in the commentary, calculated the longitude of Sirohi, (a place, 30 Yojana's West of Ujjainī) ; and from this, he seems to be a resident of that place. The name of the commentary is Mahādevī Dīpikā. It is said to contain 1500 verses. The year 1692, mentioned in the above verse, is a Samvat year of the Vikrama era, and hence, the time of the compilation of the commentary comes to be Śaka 1557.

* See line 19, Page 316.

NĀRMADA

It has already been observed in reviewing the modern *Sūrya Siddhānta* (Page 43) that there must have been a commentary on the *Sūrya Siddhānta* or some work based on it from the pen of Nārmada. The time of that Nārmada must be Śaka 1300. This point has been discussed further while commenting on the Dāmodarīya bhaṭatulya. The commentary or work is not at present appreciated.

PADMANĀBHA

He was the son of Nārmada mentioned above. His probable date was Śaka 1320, and more information about him has been given in the next para. He has written a work entitled 'Yantra-Ratnāvalī'. The author had with him, its second chapter entitled Dhruvabhramayantra, which bears his (Padmanābha) own commentary.

A review of these works will be found in the Chapter on instruments.

DĀMODARA

Dāmodara has to his credit a work, Bhaṭatulya by name. Its epochal year is Śaka 1339. The author observes,

दामोदर: श्रीगुरुपदमनाभपदारविंदं शिरसा प्रणम्य ।।
प्रत्यब्दशुध्यार्यभटस्य तुल्यं विदां मुदेहं करणं करोमि ।। २ ।।

मध्यमाधिकार.

Translation :—

Dāmodara, after saluting the Lotus-like feet of his Guru Padmanābha, compiles this karaṇa work, comparable to that of Āryabhaṭa, for the pleasure of laerned men(2)

श्रीनर्मदादेवसुतस्य मत्पितु: श्रीपद्मनाभस्य समस्य भावत: ।।
यस्मात् सुसंपन्नमनुग्रहात् गुरोर्भूयादिहैतत्पटनात् प्रदं श्रिय: ।। १६ ।।
सच्छिष्यैरसकृत् कृतप्रणतिभि: संप्रार्थितो बीजवित
वक्त्रांभोजरविश्चकार करणं दामोदर: सत्कृती ।। १९ ।।

उपसंहार.

Translation :—May the study of the work made with the favour of my father and preceptor Śripadmanābha, son of Śrinārmadadeva, bring me prosperity. (16)

The virtous Dāmodara, whose lotus face was like the Sun and who is offered continuous prayers by his good disciples, compiled this Karaṇa (work) (19)

——'Conclusion'

From this, it appears that Padmanābha was his father's name, who was also his preceptor and the name of his grandfather was Nārmadadeva. In the Dhruva-bhramayantra mentioed above, the author observes in the beginning.

श्रीनर्मदानुग्रहलब्धजन्मन: पादारविंदं जनकस्य सदगुरो:
नत्वा त्रियामासमयादिबोधकं ध्रुवभ्रमं यंत्रवरं ब्रवीम्यथ ।। १ ।।

Translation :—After saluting the feet of my father and preceptor, who was born because of the favour of Śrīnārmadadeva, I describe the best of the instruments, the Dhruvabhramayantra, which is useful in giving the time at night (1)

and in the end, the following remark is made :—

इति श्री नार्मदात्मजश्रीपद्मनाभविरचितयंत्ररत्नावल्यां
स्वविवृत्तौ ध्रुवभ्रमणाधिकारो द्वितीय: ।।

Translation :—So ends the second chapter on Dhruvabhramaṇa, in his self-written work Yantra Ratnāvalī, which is compiled by Śrīpadmanābha, son of Śrīnārmada.

It appears from this, that Nārmada was the name of Padmanābha's father and this leads one to believe, beyond all doubt, that this Padmanābha was Dāmodaras father. Dāmodara's work was written in Śaka 1339. Hence, assuming 20 years for one generation, the date of Padmanābha's work comes to be about Śaka 1320. The work, 'Jātakābharaṇa', (see section on 'jātaka' later on) written in about Śaka 1460, refers to the Dhruvabhramayantra, which lends support to the above argument. Although it does not prove beyond doubt that the Nārmada whose verse has been quoted by Ranganātha (page 43) was the father of Padmanābha, referred to in the above verse. still there is a similarity of names. Padmanābha says that Nārmada, his father, was a scholar and was also his preceptor, and it appears quite probable that he could have been the author of some work. The Nārmada, mentioned by Ranganātha, must have lived before him (Śaka 1525) and this does not give rise to any contradiction ; and the most important fact is that Dāmodara has adopted in his work, Bhaṭatulya, 54 seconds as the rate of annual equinoctial motion. This is the same as in the Sūrya Siddhānta. None of the 'pauruṣeya' (human) authors of works described so far, have adopted this notion except Dāmodara. From this, it seems beyond doubt, that Nārmada who was his grandfather, must also be the author of the commentary on Sūrya Siddhānta. The date of his commentary may be Śaka 1300.

The work 'Bhaṭatulya' has adopted epochal positions for the mean Aries Ingress of Śaka 1339. They agree with those obtained after applying the Lalla's corrections to First Āryasiddhānta. The sides and nodes are given according to the First Ārya Siddhānta. He has adopted 54 seconds as the annual equinoctial motion and Śaka 342 as the zero-precession year. More information about this will be given later on. This work contains the following chapters :—

(i) mean places.
(ii) true places.
(iii) calculation of places of five planets.
(iv) three problems.
(v) lunar eclipse.
(vi) risings and settings and
(vii) conjunctions of planets. It contains, in all, 222 verses in various metres. The author has remarked in the end that the number of verses would be 400, if composed in 'anuṣṭup' metre.

He has dealt with the chapter on 'three problems' very extensively. It consists of 87 verses, which contain some problems also and the figure 5 for the 'palabhā' has occurred a number of times in those problems. The first Ārya Siddhānta does not mention longitudes of stars. The work 'Karaṇaprakāśa which also follows the Āryapakṣa, does not give longitudes of stars. But those given by Dāmodara are some what different from what one finds in all other works. This speaks of his independent discovery in this respect. A more detailed discussion of this will be found further in the chapter on conjunctions of planets.

MAKARANDA

Makaranda is a work containing tables which facilitate the calculation of the almanac. It has been compiled by the astronomer Makaranda himself. In the beginning he observes,

श्रीसूर्यसिद्धांतमतेन सम्यग्विश्वोपकाराय गुरुप्रसादात् ।।
तिथ्यादिपत्रं वितनोति काश्यामानंदकंदो मकरंदनामा ।। १ ।।

Translation :—Makaranda, who is delight incarnate, has, by his preceptor's favour, compiled this work containing tables for calculating Tithi etc., on the basis of the Sūrya Siddhānta for the use of the world.

It shows that this work was compiled on the basis of the Sūrya Siddhānta and that the author was a resident of vārānasī. The ending moments of tithis etc., given in ghaṭis and pala's, when calculated according to this work, are found true chiefly for vārānasī. The Sūrya Siddhānta referred to in this, proves to be the modern Sūrya-Siddhānta from the theory. It is stated in the version printed at Vārānasī that the work had adopted Śaka 1400 as the epochal year. There is no other internal evidence in support of this assertion, nor does the author find any external evidence. There is, however, no reason to doubt its authenticity. Diwakar wrote a commentary on this work named Makarandavivaraṇa about Śaka 1540. The ending moments of tithis etc., and places of all planets are obtained very easily with the help of this work. The author does not describe the system for want of space. In many parts of Northern India, like Gwalior and Vārānasī, almanacs are compiled with the help of this work even at present, and these are used by the local population. This work is printed in Vārānasī. The theory underlying these tables has been explained by Gokulnāth Daivajñya in Śaka 1688, and it has also been printed.

The author of Makaranda has recommended a correction for the Sūrya Siddhānta, which has been mentioned already.

KEŚAVA

Gaṇeśa Daivajñya, the author of Grahalāghava, has written a commentary on 'Vivāhavrindāvana' which is a work by Keśava. The work, 'Karaṇakanṭhirava', was, according to Gaṇeśa also compiled by the same Keśava. This must have been a karaṇa work but it could not be procured anywhere. This Keśava was an Audicya Brāhmaṇa of Bharadvaja Gotra. The names of his forefathers, beginning from his father in ascending order, were Rāṅaga, Śriyāditya and Janārdana. This Keśava must have lived earlier than the Keśava, the father, of Gaṇeśa, the author of Grahalāghava. Nirṇayamṛta, a commentary on Pitāmbara's Vivāhapaṭala, written in Śaka 1446, refers to the

annual rates of motions. This difference will become very great as time will elapse, since the Brāhma and other Siddhāntas themselves show a great discrepancy in the numbers of revolutions and the number of seven days etc. Much greater difference will occur after the lapse of a long time.... Hence, the future calculators should calculate planetary places, by adopting the figures of revolutions increased or decreased in conformity with the actual observed phenomena of the conjunction, rising and setting of stars and planets in their own time. Otherwise, short karaṇa works should be compiled by adjusting the epochal positions true for the moment in question. The writer has accordingly found out the mean place of the moon, instead of its maximum equation of centre, by reversed steps, from the observation of the lunar eclipse at the ending moment of the full moon, since, the equation of centre is neither positive nor negative. The moon's apogee was finally fixed by reversing the steps of calculation, after observing the eclipse at the moment of the full moon in the celestial globe of observation, since the maximum correction would neither be plus nor minus. The moon's place was found to be 5 minutes less as compared with that calculated from the Sūrya Siddhānta. The apogee agreed with that of the Brahmapakṣa. The sun's place showed a small discrepancy in the case of all 'pakṣas'; hence, the writer accepted that belonging to Saurapakṣa. Places of other planets were fixed after actually observing their positions at the time of their conjunctions with stars and planets. Here the writer has taken the Mars and Jupitar as derived from the Brahma Siddhānta and Mercury's place from Brahmapakṣa. Venus was taken as occupying the mean position between the Ārya and Brahmapakṣa. The Saturn was seen to exceed the position given by the three pakṣas by five degrees. Thus the writer has calculated the places of planets by a short method after observing their actual places at the present time.

The writer has not found such a detailed account of results of observations personally taken by any other astronomer and recorded in his own work. As a matter of fact he inclined to think that there never lived another astronomer like Keśava, except the author of the original Sūrya Siddhānta, Āryabhaṭa I, Brahmagupta and the astronomers living in the time of king Bhoja. If he had recorded the day on which the observations were taken and what were the planetary positions found from observation, the record would have been very useful. But it is a matter of regret that tradition never induced the astronomers in our country to record such an account in their own works.

The writer found from calculation that he has adopted in his work, *Grahakautuka*, such epochal positions and annual motions as agreed with his observations.

Keśava has himself written a commentary on the *Graha Kautuka* and the *Jātakapaddhati*.

GAṆEŚA DAIVAJÑYA

He was a very famous astronomer. The astronomical works of no other astronomer are in use all over India at present as those of Gaṇeśa Daivajñya.

His father's name was Keśava, mother's name Lakṣmi, Kauśika his gotra and Nāndgāon, on the western sea-coast, his place of residence. These facts havlready been stated above.

Viśvanātha, in his commentary "Viśvanāthī" on Graha Lāghava, observes, "the works which Gaṇeśa Daivajña, my preceptor compiled, have been enumerated by his nephew, the astronomer Nṛsiṃha, in two verses in his commentary on Grahalāghava. They are :—

HIS WORKS

कृत्वादौ ग्रहलाघवं लघुबृहत्तिथ्यादिचिंतामणी ॥
सत्सिद्धांतशिरोमणौ च विवृतिं लीलावतीव्याकृतिं ॥
श्रीवृंदावनटीकिकां च विवृतिं मौहूर्ततत्त्वस्य वै ।
सत्श्राद्धादिविनिर्णयं सुविवृतिं छंदोर्णवाक्यस्य वै ॥ १ ॥
सुधीरंजनं तर्जनीयंत्रकं च सुकृष्णाष्टमीनिर्णयं होलिकाया
लघूपायपातस्तथान्या:.........."

Translation :—Gaṇeśa Daivajña appears to have compiled the following works :—The Grahalāghava, the Laghutithi Cintāmaṇi, the Brihattithicintāmaṇi, the Siddhāntaśiromāṇiṭika, the Līlāvatiṭikā, the Vivāhavṛndā vanaṭikā, the Muhūrtatatvaṭikā, the Śrāddhanirṇaya, the Candorṇavaṭikā, the Tarjanīyantra, the Kṛṣṇāṣṭamīnirṇaya, the Holikānirṇaya, the Laghupāyapāta (i.e. a table for calculating Mahāpāta), etc.

Even Gaṇeśa has himself mentioned the names of some of his works in his work, *Vivāhavṛndāvanaṭīkā*. They are,

कृत्वादौ ग्रहलाघवाख्यकरणं तिथ्यादिसिद्धिद्वयं
श्लोकै: श्राद्धविधिं सवासनतया लीलावतिव्याकृतिं ॥
सप्रेक्षपमुहूर्ततत्वविवृतिं पर्वादिसन्निर्णयं ॥
तस्मान्मंगलनिर्णयाद्यथ कृता वैवाहसद्दीपिका ॥

Translation :—(Not necessary)

This list mentions the additional work, Parvanirṇaya. It is not that these works have been mentioned in their chronological order. Still, the *Grahalāghava* appears to have been compiled first. In this work, Śaka 1442 has been adopted as the epochal year for planetary calculation. At this time he must have been at least 20/22 years of age. In other words his date of birth may have been about Śaka 1420. The work *Laghucintāmaṇi* was written in Śaka 1447 and the Līlāvatiṭīkā in Śaka 1467. The *Pātasāraṇi* shows that it was compiled some time after Śaka 1460. The author has seen a printed Edition of Vṛndāvanaṭikā and it has mentioned its date of compilation in a curious way. It is given thus :—

The Dates

हायनार्क १२ लवसुल्यमायनं तद्युतीरस ६ युता युतिर्भवेत् ॥
सापि सागर ४ युतोडुपोद्रुकं नत्त्रिनेत्र २३ लव एव पक्षक: ॥ १ ॥
पक्ष: सपक्षो २ यदि वासर: स्यात् तदीयरामां ३ शसमस्तिथि: स्यात् ॥
यच्चाखिलैक्यं* कुयमा २१ हतं तत् नंदा ६ धिकं मत्वाकवत्सरा: स्यु: ॥
उदयनतिथिपक्षास्तुल्यतां यांति यस्मिन्.........॥

* (Saṃvatsara 12th + Ayana 1st + Yoga 19th + Nakṣatra 23rd + Pakṣa 1st + Week day 3rd + Tithi 1st + Month 11th) $\times 21 + 9 = 1500$.

Gaṇeśa Daivajñya states how the planets would agree with the positions calculated from ancient works :—

सौरोर्कोपिविधूच्चमंककलिकोनाब्जो गुरुसत्वार्यजो- ।।
ऽसृग्राहू च कुजज्ञकेंद्रकमथार्य: सेषुभाग: शनि: ।।
शौक्रचं केंद्रमजार्यमध्यगमितीमे यांति दृक्तुल्यतां ।।

मध्यमाधिकार.

Translation :—(not necessary, since the sense is given in the following para). The places calculated for Sunrise on Monday, the New Moon day of Phālguna of Śaka 1441, according to the instructions given above agree completely. That is, calculated from the modern Sūrya Siddhānta, the places of the Sun, and the Moon's apogee and that of the moon diminished by 9 minutes would agree with the positions given above. Calculated from the Karaṇaprakāśa of the Āryapakṣa, the places of Jupiter, Mars, the Moons' node and that of Saturn increased by 5°, would agree with the positions mentioned above. The anomaly of Mercury agrees with that calculated from the Karaṇakutūhala of Brahmapakṣa; and the anomalies of Venus, as calculated from Karaṇaprakāśa and Karaṇakutūhala agree with the above position when added up and halved. Gaṇeśa has, however, left out seconds of arc in all the position and increased or decreased the minutes in some cases ; hence, in certain cases, there is some discrepancy as far as minutes of arc are concerned. While calculating the places mentioned above, the ahargaṇa for Karaṇaprakāśa comes to 156334 and that for Karaṇakutūhala to 123113*. It is obvious how very laborious it would be to make calculations with these figures of ahargaṇa. Gaṇeśa has advocated the method of calculating planets' places from the ahargaṇa itself ; but he has employed a device by which the ahargaṇa figure is not allowed to increase too much. He has assumed a cycle of the ahargaṇa of 4016 days, since this happens to be the approximate number of days in the period of 11 years; and the planet's mean motion during this period is termed the "dhruva'. The application of this motion** gives the mean place. The ahargaṇa never exceeds the number 4016 because of this device.

HIS SPECIALITY

Another speciality of the *Grahalāghava* is that it has done away with the use of sines and arcs. Inspite of this there is absolutely no harm in saying that this work gives results by no means less accurate than those obtained from any of the earlier Karaṇa works. Modern English works give tables of sines not only for each degree, but even for each minute of arc ; and some works are so compiled that they give the sines of even seconds of arc. Our works give sines of angles of $3\frac{3}{4}$ degrees and their multiples. Thus, the number of tabular sines is 24 ; but the karaṇa works generally give only 9 (at an interval of 10°) or even less. Even though the Grahalāghava has not used the sines, the method of finding the sun's true places, as adopted by Grahalāghava,

* No commentator has pointed out just as the author has done, the particular works from which the different planetary places have been derived by Gaṇeśa Daivajñya.

** The period of 11 years gives a variable number of days ; and the author has so adopted the device that the error corresponding to this variation would not escape.. The explement of the planet's motion in the cycle is given ; if this explement subtracted from the epochal position and the motion for the ahargaṇa added to the remainder, the mean position of the planet for the given moment.

those calculated from the European works, the basis of comparison being theirr elation to the Sun.

Planet	°	′
Sun	0	0
Moon	—0	2
Moon's apogee	+1	55
Moon's node	—0	17
Mars	+0	44
Mercury's Śīghrocca	+8	21
Jupiter	+0	58
Venus's Śīghrocca	+1	22
Saturn	+1	29

It appears from this that Mercury's place is very erroneous. The places of Venus, Saturn ard Moon's apogee show a discrepancy of 1° to 2°. Others show a difference within 1°. The Moon's place is remarkably correct. The place of the Moon's node is not very erroneous. Gaṇeśa's father, Keśava, has already mentioned in the account of his work, about his claims that he ascertained the place of the Moon and Rāhu from the Solar eclipse. It appears that there is such a serious discrepancy in Mercury's place, because, Mercury is not easily observable as it is visible only for a few days in the year. Another fact that must be remembered is that the above errors occur in the mean places of planets. But only the true places of planets are found by actual observation. While considering Bentley's method, it has already been shown on page 30, that the discrepancy in the actual places of planets at the time of the *Grahalāghava* might have been much less. It has been shown later on in almanacs what is the extent of error seen at present while calculating figures from the *Grahalāghava.*

Gaṇeśa observes that the places of planets calculated from certain works tally with their observed places on application of certain corrections; accord-dingly he has suggested a correction of 5° for Saturn's place, which is very excessive. Similarly he has proposed a correction of some minutes of arc in the case of other planets also. It is quite obvious, therefore, put forwarded the names of ancient works only by way of nominal support while recording the actual positions of planets in his own time.

Keśava, Gaṇeśa's father had almost prepared the ground for applyirg corrections to old works by taking observations, as he had noticed discrepancies in the planets' places obtaired from the earlier works, and he compiled the Graha Kautuka accordingly; Gaṇeśa observes in Laghu Cintāmaṇi that he finally corrected the planets after observing the loopholes still left in that work. A comparison of Graha Kautuka and Grahalāghava would confirm this statement. In the Chapter on the risings and settings, in Grahalāghava, he remarks :—

पूर्वोक्ता भृगुचंद्रयोः क्षणलवाः स्पष्टा भृगोश्चोनिता ॥
ब्राम्यां तैरुदयास्तदृष्टिसमता स्याल्लक्षितैषा मया ॥ २० ॥

Translation :—*(not necessary)*

In this he says that it was his experience that the moments of risings and settings of Venus are found to be true when the kālāṃśas mentioned by earlier astronomers are diminished by two. All these things go to prove that he was himself an observer. One of the legends that has become quite current about him, says that it was not necessary for him to look to the ground, while walking, because his feet had got eyes. This is of course, an impossibility. Still it goes to show that his attention was always directed to the sky while walking. Another legend says that he was always found to be gazing at the sky while sitting on huge slabs of stone on the seashore. This was quite possible. Many such slabs are found on the sea coast in Kankan and it is very convenient to take observations while sitting in such quiet places.

Calibre

Gaṇeśa was perhaps able to produce a work like the *Grahalāghava* which proved more accurate in the light of observation than Graha Kautuka, because his own experience was coupled with that of his father ; and although the methods described in Graha Kautuka are, in some cases, more convenient than those of Grahalāghava, still, in certain other matters, the Grahalāghava is found to be more convenient. Hence, Graha Kautuka may have gone out of use giving place to Grahalāghava. Considering all things I am inclined to think that his father was more competent than Gaṇeśa himself. However, looking only to the utility of the works the *Grahalāghava* is certainly superior because the experience of both father and son have been combined in that work.

The *Grahalāghava* contains chapters on the following 14 subjects:— (1) Mean places (2) True places (3) Places of five planets (4) Three problems (5) Lunar Eclipse (6) Solar Eclipse (7) "Māsagaṇagrahaṇa" (8) Approximate places of planets (9) Risings and settings (10) Shadow (11) Shadow of stars (12) Elevation of Moon's Cusps (13) Conjunctions of planets (14) Mahāpāta. They contain respectively 16, 10, 17, 26, 13, 13, 19, 8, 25, 6, 12, 4, 4 and 14 verses in different metres and 187 verses in all. At present only these 14 chapters are widely known. But the commentaries of Mallāri and Viśwanātha contain a 15th Chapter of 15 verses entitled 'Pañcāṅgagrahaṇa'. Since the 14 chapters already include 4 chapters devoted to eclipses, this must have been considered superfluous and allowed to be lost. Gaṇeśa appears to have purposely sacrified accuracy in certain cases because of his tendency to simplify calculations and hence, he has added two more chapters on eclipses (7th and 8th) even when 2 chapters out of 14 had been devoted to the eclipses of the sun and the moon. The addition was altogether redundant. Grahalāghava appears to also have undergone certain changes in its different versions. In the copy of the *Grahalāghava* written in Śaka 1605, which the author got at Bārśi the 15th Chapter had been omitted while the chapter on 'Pañcatārā contained 3 more verses which discuss some points about planets' risings and settings. These verses are not found in Viśwanātha's commentary. Some verses show variations in readings. Again the Viśwanāthī commentary contains some verses which are not found in the copy of the *Grahalāghava* printed by Kṛṣṇaśāstrī Godbole. A verse describing the method of calculating the moon's latitude accurately is given in the Viśwanāthī commentary and also in Kṛṣṇa Śāstrī's edition, but it was not found in the copy obtained by author at Bārśi. Different copies of the work give the sequence of certain verses in different ways. It is found at present in the chapter on 'nakṣatrachāyā' a

verse, attributed by Viśvanātha to Nṛsiṃha, nephew of Gaṇeśa, but it is not to be found in the Bārśī-copy. Anyway, even though there are some variations here and there, they have not given rise to any perversion so far as the author's original methods are concerned.

Other works.

Among other works of Gaṇeśa that are useful for the calculation of the almanac, Bṛhatcintāmaṇi and Laghucintāmaṇi are particularly noteworthy. They are helpful in quickly calculating figures for tithi, nakṣatra, and yoga. If tithi and other items of the almanac (pañcāṅga) were to be calculated by actually finding the true places of the sun and moon from the *Grahalāghava*, they would require unremitting labour for six months. If the tables prepared for calculating the mean and true positions of the sun and the moon are utilized, even then one would take according to the author's estimate, about 24 days, of ceaseless labour. But the work Laghucintāmaṇi expedites the calculations to such an extent that the tithis, nakṣatras and yogas could be calculated only in three days. The work can be finished still more quickly if the *Bṛhatcintāmaṇi* is used. And inspite of this economy of labour, it is found by comparison that the difference in ghaṭipalas as obtained from Tithicintāmaṇi and those calculated direct with the help of Grahalāghava, never exceeds 30 palas. I do not propose to describe the nature and scope of Tithi Cintāmaṇi* for want of space. No such work was compiled by any one before Gaṇeśa Daivajñya. The work entitled Makaranda which has already been described before (page 127), helps quick calculations ; but its method is somewhat different, and its date is Śaka 1400, still, Gaṇeśa may not have even seen it at all. Hence, there is no harm in giving full credit for originality to the author of the *Grahalāghava* or having produced a work like the *Tithi cintāmaṇi* which is so very useful in calculation and which reduces one's labour to the barest minimum.

Impeachment

Kero Lakṣmaṇa Chatre has accused Gaṇeśa Daivajñya in the following works :—"He simplified calculations by employing easy devices......but, because of this, the results became approximate to that extent and this laid the foundation of future erroreous methods......Another result has been ....that the tradition of studying the Siddhānta works and of taking observations disappeared and the astronomers are deprived of the knowledge of the basic astronomical theory**. There are also some others who accuse the author of the *Grahalāghava* in the same way. But while considering Gaṇeśa Daivajñya's work, it is no use accusing him for his approximate results by comparing his work with the modern European works. It should be considered what could be the best possible achievement with the means available in his time. Keropant Nānā and other critics do not seem to have considered this aspect of the question because there had been no means so far for judging the question whether earlier authors of Karaṇaworks could secure greater accuracy than Gaṇeśa or what original work was done by him with regard to the taking of observations. If the value of his work from this point

---

*Keropant has, in his tables of Planetary Calculations, described the method of calculating tithi which is exactly the same as that given in Gaṇeśa's Tithicintāmaṇi. The underlying theory has not been explained. But the author has explained, in an article in the issue of the Indian Antiquary for April 1887, the theory underlying every step of the method together with an illustrative example.

**Introduction to Keropant's Planetary Tables, P-2.

of view be estimated there would be absolutely no room left for accusing Gaṇeśa Daivajñya. Again, if less laborious methods yield the same results as the extremely laborious calculations gave from Siddhānta works, why should not such methods be accepted ? There is no harm in saying that Gaṇeśa was not at all inferior to earlier astronomers in securing accuracy of results for any problem even while attempting to simplify the work of calculatior. Again it will be seen from the relation which the author has so far traced between all, the siddhānta and karaṇa works, that Keropant was wrong in accussing Gaṇeśa of having laid the foundation of erroneous methods. If he means to say that the length of the year (adopted by Gaṇeśa) was inaccurate, the error had persisted from the very beginning. The author thinks that there were very few astronomers among the predecessors of Gaṇeśa in whom ingenuity and perseverance were so happily blended.

He was undoubtedly superior to Bhāskarācārya in the matter of observations. Now-a-days the tradition of studying the Siddhānta works is almost lost. Not to speak of the Siddhānta works, one comes across very few astronomers who have thoroughly studied at least the *Grahalāghava* in its entirety. But this is not the fault of Gaṇeśa's works. Later history will show that he was succeeded by many more astronomers who understood the secrets of the Siddhānta works, who themselves compiled the Siddhānta works and who were also observers. Gaṇeśa himself has written a commentary on Siddhānta Śiromaṇi and Līlāvatī. As regards compiling a work on theory, the work was already done by Bhāskarācārya. It is of course true that he was not attracted to make new discoveries of the kind made in Europe in his time, but it is not proper to blame Gaṇeśa Daivajñya on that account, for the zest for knowledge was, waning among the people at large and, for several other reasons, the love of research had very nearly vanished.

Commentaries

There is a commentary on the *Grahalāghava* written in Śaka 1508 by Gangādhara of the Tapar Village. Mallāri Daivajñya wrote his commentary in the year Śaka 1524. It contains the astronomical theory. The Viśvanāthī commentary belongs to Śaka 1534. It contains illustrative examples. The commentary is also known as 'Udāharaṇa'. The last two of these commentaries are printed. Calculations are seldom made from the *Bṛhat Cintāmaṇi* because it contains too many tables ; for this purpose of calculation people prefer the Laghu Cintāmaṇi which is printed. It is full of figures and the errors in these figures which have been accumulating for generations have now grown to an enormous extent. Most of the tables have been corrected. There is a commentary, Subodhini by name, written on Bṛhat Cintāmaṇi by Viṣṇu Daivajña, which expands the theory. Cintāmaṇi Kānti, a commentary on the *Laghucintāmaṇi*, is written by Yajñeśvara, an astronomer. It contains the theory. The commentaries on the *Muhūrtatatva* and the *Vivāhavṛndāvana* have been printed. Tarjaniyantra is a work meant to be used for ascertaining time. It is also called the *Pratoda yantra* ; it is commented upon by Sakhārāma. There is another commentary by Gopinātha, a resident of Saṃgameśvar. The name of Gopinātha's father was Bhairava and that of his grandfather was Rāma. This work will be further dealt with in the chapter on instruments.

There are two other Gaṇeśas, different from the author of the *Grahalāghava* ; one of them is the author of the *Tājak Bhūsaṇa*' and the other of the *Jātakālaṃkāra*.

A legend

This account of the author of the *Grahalāghava* will be closed recounting a legend after about him. Keśava, his father, once predicted the moment of an eclipse. The king of the country, who was a yavana, somewhat ridiculed him, as the prediction did not come true. Keśava was very much grieved over this. He, therefore, started a penance in the temple of Gaṇapatī at Nandigrāma. He had grown old at that time. Looking to his sad plight and firm devotion, Gaṇapatī told him in a dream that he (Keśava) would no longer be able to continue the work of observing and rectifying the positions of planets and that, Gaṇapatī would therefore himself come to birth as his son to do the work for him. Accordingly, a son was born to him, who was named Gaṇeśa. People at present regard him as an incarnation of God. Two more stories about him have already been told. All such stories indicate the reverence for him on the part of the people. If once an intelligent person comes to be regarded as divine incarnation, the feeling grows strong that his achievement can never be equalled and this very feeling has been mainly responsible for the absence of discoveries in our country.

His Descendants

It appears that many of the descendants of Keśava and Gaṇeśa were also scholars. Ananta, Gaṇeśa's younger brother, wrote a commentary on Varāha Mihira's Laghujātaka, in 'Jaya' Saṃvatsara (Śaka 1456), and Ananta claims that it is shorter and easier than that of Utpala. Ananta had been guided in his studies by his brother Gaṇeśa. It appears from the Viśvanāthī commentary that there was a commentary on Grahalāghava by Nṛsiṃha, Gaṇeśa's nephew, but it could not be procured any where. Gaṇeśa had a son named Keśava, whose son Gaṇeśa wrote Śiromaṇiprakāśa, a commentary on the *Siddhānta Śiromaṇi*. It may have been written about Śaka 1520. A later descendant in his family, namely Keśava, son of Rudra, compiled a work entitled Lagnakalā Pradipa, in Śaka 1629, the name of the saṃvatsara being Sarvajit.

KALPADRUMA KARAṆA

A reference to this Karaṇawork occurs in the commentary on the Karaṇ Kutūhala, written in Śaka 1482. The commentary shows that the Kalpa druma Karaṇa was compiled by an astronomer, named Rāmacandra, and that he has mentioned a correction to be applied to the Karaṇa Kutūhala. The figures, indicating corrections known as 'Rāmabīja' which have been mentioned in the works of Dinkara and Śrīnātha to be described later on, are different from those mentioned by this commentator. From this it appears that the Rāma-corrections mentioned in the works of Dinkara and Śrīnātha must have been different.

LAKṢMIDĀSA—(Śaka 1422)

He wrote a commentary, known as Gaṇitatatvacintāmaṇi, on the Gaṇitādhyāya and Golādhyāya of Bhāskara's Siddhānta Śiromaṇi. It contains 8500 verses, and gives theory and illustrative examples. His gotra was Upamanyu ; Vācaspatimiśra, the name of his father; and Keśava, that of his grandfather. The Śaka figure of 1422, adopted by him for the main example, has been taken by him as 'current'. The solved example on eclipse refers to the Kali elapsed year 4599 (i.e. Śaka 1420). The reasons which led him to compile the commentary have been described by him in the following verse :—

शिरोमणिविबोधने सुजननागनाथेरित: सुहृदगुणगणाकरःप्रगुणदेवनाथार्थित: ।।
हितैरनघराघवैरपि निजानुजोर्वीधर प्रियप्रतिविधैषयास्मिविविधप्रयत्नोन्मुख: ।।

Translation :—

With a view to please the scholars, being instructed by Nāganātha, requested by Devanātha, by Urvidhara, the younger brother and by all well wishers, the writer is making efforts to explain the Siddhāntaśiromaṇi.

Lakṣmidāsa appears to have been a good poet.

JÑĀNARĀJA—(Śaka 1425)

GENEALOGY

Rāma (of Bharadvāj gotra)
|
Nilkanṭha
|
Viṣṇu
|
Nilkanṭha
|
Nāganātha
|
Nṛsiṃha
|
Nāganātha — Ḍhuṇḍhirāja
|
Jñānarāja — Gaṇeśa (son of Ḍhuṇḍhirāja)
|
Sūrya — Cintāmaṇi
Nāganātha
Gopāla (Jñānarāja)
|
Rāmchandra
|
Vijñāneśwara
|
Puruṣottama
|
Kāśinātha

Jñānarāja was born in a famous family of learned men, which can boast of an unbroken tradition of scholar even to this day. A learned gentleman, from Bid in the Nizam State, and Kāśinātha Śāstri by name, once met the author at Bārśi in Śaka 1807. The author had taken notes of the brief history of his family which was told by Śāstri. Finding that it agreed with the family history of Jñānarāja, he requested him by a letter recently (Śaka 1817) for further information. He sent him some additional information and the genealogical tree. The genealogical table given in the margin has been prepared by the author on the basis of this information, and the note on Jñānarāja in the 'Aufrecht' catalogue, and also on the basis of the information so far gathered by him. The names of only the first five ancestors of the family have been given from the Aufrecht's table. Even on this point the cross-references at three places in the catalogue showed some contradiction. The author has not ed the names which seemed most consistent with the context. The first man, Rāma, noted in the list has been pointed out in the Aufrecht Catalogue as flourishing at the court of King Rāma of Deogiri. In the genealogical table, sent by Kāśinātha Śāstri, the name of Nṛsiṃha's father has been stated to be Daivajñarāja and the list begins from that name. It appears that Nāganātha or some earlier ancestor of the family might have received. the title of Daivajñyarāja. The family history recorded below will show that in the list of ancestors sent by Kāśinātha Śāstri, there must have been a break after Sūrya or before Gopāla.

PLACE

According to the Aufrecht catalogue, Rāma was a resident of Pārthapur. Sūrya Paṇḍit who wrote Amṛta Kūpikā, a commentary on Bhāskara's Līlāvatī, has described his father and grandfather in it. He observes,

आस्ते त्रस्तसमस्तदोषनिचयं गोदाविदर्भायुते:
क्रोशेनोत्तरतस्तदुत्तरतटे पार्थाभिधानं पुरं ।।
तत्राभूदगणकोत्तम: पृथुयशा: श्रीनागनाथाभिधो
भारद्वाजकुले सदैव परमाचारो द्विजन्माग्रणी: ।। १ ।।

Translation :—"Pārthapur, a village situated on the northern bank of river Godāvarī, about 2 miles away from the confluence of the Godāvarī and the Vidarbhā, there lived a Brāhmaṇa astronomer, named Nāganātha, belonging to Bharadvāj Gotra."

In the comentary on Bhāskara's 'Bīja' he observes :—

गोदोदक्तटपूर्णतीर्थनिकटावासे तथा मंगला...
गंगासंगमतस्तु पश्चिमदिशि क्रोशांतरेण स्थिते ।
श्रीमत्पार्थपुरे बभूव.........श्रीनागनाथाभिध: ।।

Translation :—(not necessary, since it carries the same sense as the above verses).

We find at present, a village named Pātharī near the north coast of Godāvarī and about 70 miles to the east of Paiṭaṇā. This is the same as pārthapur. It is about 85 miles to the S.E. of Deogiri (Daulatābād). The river Vidarbhā was probably known by another name Mangalā. The above description shows that this Pārthapur was about 2 miles to the N.W. of the confluence of this river and the Godāvarī. Kamalākara Daivajñya says while describing Pātharī (See note on Viṣṇu later on) that the city was located in the Vidarbhā country, and it was the capital city of kings and was situated 16 yojanas to the S.E. of Deogiri. Reckoning one yojana as equal to 5 miles, the figures 16 yojanas appear to be correct. Some other works written during this period have also named the country surrounding Pātharī as Vidarbhā country.

DATE

The epochal positions which Jñānarāja has given in his work, Siddhānta Sundara, are true for Śaka 1425. This was evidently his date. Assuming 30 years for each generation, the date of Rāma, the first ancestor in the genealogical table comes to about Śaka 1215, and it agrees with that of king Rāma of Deogiri.

Jñānarāja has written a work on astronomy, called Siddhānta Sundara. I have seen the main parts of Siddhānta Sundara, viz., Golādhyāya and Gaṇitādhyāya. (Book No. 4350 in Ānandāśrama). The Golādhyāya in it contains 6 chapters: 'Bhuvanakośa', 'Madhyagatihetu,' 'Chedyaka', 'Maṇḍalavarṇana', Yantramālā and 'Rituvarṇana'. It contains respectively 79, 30, 21, 16, 44 and 34 verses. The Adhyāya on 'gaṇita' (mathematics) contains the following *Adhikāras* :—Mean places, true places, three problems, probability of eclipses, lunar eclipse, solar eclipse ; risings and settings of planets, shadow of stars,

elevation of Moon's cusps; planetary conjunctions and Mahāpāta. They contain 89, 48, 43, 7, 40, 16, 19, 20, 18, 10 and 11 verses respectively. The Siddhānta Sundara has a commentary compiled by Cintāmaṇi, the son of Jñānarāja ; and a reference at one place in it indicates that the Sundara Siddhānta contained algebra also ; but the author has not seen it. Sudhākara *Dvivedī says that it resembles the portion on 'bījachāyā' by Bhāskara, and that the aphorism "sarupake varṇakṛtītu yatra" meaning 'has been refuted, in it'.

The Siddhānta Sundara, follows the modern Sūrya Siddhānta. Like a karaṇa work, it gives the epochal positions of planets and annual rates of motion for finding the planets' places. The epochal positions are true for Śaka 1425. The moment for which they are true is not mentioned. But the author has found from actual calculation that they have been calculated for the moment of 56 ghaṭis 39 palas after sunrise on Thursday, the 8th lunar day of the bright half of Āśvin in that year. These positions and the rate of yearly motion of the planets, completely follow the modern *Sūrya Siddhānta*. The epochal positions appear to have been given for an odd moment. But the mean longitude of the Sun in it is $6^s\,0°\,14'\,17''$, which shows that it is true for a moment exactly 15 ghaṭis after the mean Libra Ingress. From this, his object seems to give the positions for 15 ghaṭis after the mean Libra Ingress. A correction to planetary places has been mentioned in the chapter on mean places.

खाभ्रखाभ्राष्टभू १८०००० भिर्गतं यत्कलेस्तष्टमेतस्य यातैष्ययोल्पकं ॥
तद्रवा १ पावकै: ३ सिद्ध २४ संख्यैर्हतं दृग्यमै: २२ खाग्निभि: ३० खांककै ६०
वंन्हिभि: ३ ॥ ८३ ॥
नंद ६ विग्नायुतेना १०००० प्रभागैर्युता: सूर्यसौरावनीजा: परे वर्जिता: ॥
द्क्समत्वं ग्रहाणामनेन स्फुटं प्राह दामोदराचार्य एवं बुध: ॥ ८४ ॥

Translation :—

A correction for the modern *Sūryasiddhānta* has been mentioned before page 45) ; this is 30 times that correction ; otherwise it is the same as that one in all respects. The correction to be applied to the Sun according to the figures given on page 45 comes to 6″only. This is negligibly small. Dāmodara's correction, as mentioned by Jñānarāja in the case of the sun, for the above mentioned year comes to 3′. This appears to be a more probable correction-figure. If the reading 'bhāgādi' given in the 7th verse of the chapter on 'Bījopanayana' in Sūryasiddhānta, be changed to 'Rāśyādi', the correction mentioned therein would exactly agree with that given by Dāmodara. The reading 'bhāgādi' seems to be the copyist's error, and one is led to infer that the correction given in the Sūrya-Siddhānta (page 45) owes its origin to Dāmodara himself. The annual correction to be applied to the sun's place, as mentioned by Dāmodara, comes to $+1/25''$. This reduces the length of the solar year by $2^v.\text{-}26^{pv}.\text{-}6^{ppv}$ (vipalas etc.) that is, the length of the year, $365^d\text{-}15^{gh}\text{-}31^p\text{-}31^{vp}.\text{-}24^{pv}$ becomes $365^d\text{-}15^{gh}\text{-}31^p\text{-}28^v\text{-}57^{pv}\text{-}54^{vpv}$. The account of one Dāmodara who lived about the Śaka year 1339 has been given before, on page 125, and he must be the same as this very Dāmodara.

Jñānarāja does not appear to have mentioned the ayanāṃśas of his time. He has simply explained the term 'ayanāṃśa' as the difference between the sun's

*Sudhākara Dvivedi, teacher of Mathematics at the Sanskrit College, Vārānasī wrote a book entitled, *Gaṇaka Taraṅginī*, in Sanskrit in Śaka 1814 has been printed. See page 60 of the book. The book contains an account of astronomers.

position calculated from the shadow cast by the noon sun and that obtained from 'calculation' based on a Karaṇa work. The annual rate of equinoctial motion has been said to be 1′. He has also given the method of finding ayanāṃśa as described in the Sūrya-Siddhānta. The rate of annual motion when calculated by it comes to 54″.

Jñānarāja, after mentioning the opinion of the Śrutis and Purāṇas about the increase and decrease of the moon's digits, observes, in the chapter on the elevation of the moon's cusps :—

वेदे सुरा: सूर्यकरा: प्रसिद्धास्त एव यच्छंति कला: क्रमेण ।।
सितेऽसिते ते क्रमशो हरंति ।। ६५ ।।

Translation :—

"The sun's rays themselves are known in the Vedas as Gods. They gradually add the objects to and carry them away from the moon in the bright and dark half of the month."

The Sundara-Siddhānta gives nothing new as established by observation. Some explanations of theory, however, are different from those of Bhāskara. The chapter on Yantramālā describes one new instrument. There is no harm in saying that the work Siddhānta-Sundara is on the whole beautiful as the title suggests.

Other Works

Sūrya has recorded in his commentary on Bhāskara's Bījagaṇita that Jñānarāja has, in addition to the Siddhānta, written a work, on each of the following subjects ; astrology, rhetoric and music.

Account of Descendants

An account of his descendants Ḍhuṇḍhirāja, Gaṇeśa and Sūrya has been given for each separately later on. It has been already mentioned before, that Cintāmaṇi wrote a commentary on Sundara-Siddhānta. Here the author gives an account of some of the remaining descendants on the basis of the information supplied by Kāśīnātha Śāstrī. It is not known when this family shifted from Pātharī to Bid for permanent residence. Bid is a place about 50 miles to the W.S.W. of Pātharī, and about 60 miles to the South of Daulatābād and 50 miles to the S.E. of Paiṭaṇā. Nāganātha has compiled a commentary named Narapati jayacārya. Puruṣottama has written Keśavī Prakāśa and Varṣa saṃgraha, two works devoted to astrology and written another work entitled Datta Kutūhala. He writes in the Keśavī Prakāśa that Rāmacandra was proficient in the science of astrology and that Vijñāneśvara was a scholar of logic, grammer and astronomy, and was honoured by king Bāji Rao. This Bāji Rao was the last Peśwa (Śaka 1717 to 1739). Kāśīnāha Śāstrī is still living and he is a scholar of logic, grammer and astronomy. He is the highest officer at Bid. He is very much honoured in the Hyderābad State. He has been honoured by the Śankarācārya of Hampi Virupakṣa, who conferred on him the title of Sūri Cūḍāmaṇi. He has complied a work entitled Nyāyāpota and is engaged in writing the work Śrī Devī Bhāgavat Cūrṇikā, of which he has compiled five chapters.

Sūrya (Birth Śaka 1430)

He was the son of Jñānarāja, the author of Siddhānta-Sundara. He has written a commentary on Bhāskara's 'Bīja' in which he has called himself Sūryadāsa and the work, Sūrya Prakāśa. He has stated that he wrote the commentary in Śaka 1460, that is in his 31st year. From this, his birth year comes to either Śaka 1429 or 1430. This commentary contains 2500 verses. At some places he has given his name simply as "Sūrya". He has written a commentary, *Ganitāmṛta Kūpikā* on Bhāskara's Līāvatī. It belongs to Śaka 1463. The theory in it has been explained by numerical quantities, and regarding the work Līlāvatī as a poem, he has given several interpretations of some of the verses in it. This commentary contains 3500 verses. Both these works have a verse given at the end which cites the names of eight works written by him. They are :—

Līlāvatī Ṭīkā, Bīja Ṭīkā, Śrīpatipaddhatigaṇita, Bījagaṇita, Tājikagrantha, Kāvyadwaya, and a work on metaphysics entitled *Bodhasudhākarā.* The fourth of these, Bījagaṇita, is his own independent work. The title of the Ṭājika work is *Tājikālankārā.* There is a copy of the work in the Deccan College Collections. This copy also contains the above mentioned verse, though the word 'Kāvyāṣṭaka' is found there in place of 'Kāvyadwaya'. Even the information sent by Kāśīnātha Śāstrī reveals that Sūrya Pandit compiled 'kāvyāṣṭaka' and the names of the 8 works are given thus. 'Padyāmṛtataranginī'; Rāmakṛṣṇa Kāvya, Śankarābharaṇa, Nṛsiṃha Campu, Vighna Mocana, Bhagavatīgīta etc. The poem 'Rāmakṛṣṇa Kāvya' is well known and its verses are capable of double interpretation, one of which applies to Rāma and the other to Kṛṣṇa.

Colebrooke *writes, "He (Sūryadāsa) was the author of a complete commentary on the *Siddhānta Śiromaṇī*, and of a distinct work on Calculation, under the title of *Gaṇitamālati* and of a compilation under the name of *Siddhānta-Saṃhitā-Sār-Samuccaya*, in which he makes a mention of his commentary on the *Śiromaṇī*". These three works have either been included in the above-mentioned verse enumerating his works, or in the information sent by Kāśīnātha Śāstrī, nor have they come to the authors' notice. The Aufrecht catalogue recording the names of works written by Sūryasuri or Sūryadāsa or Sūrya, include the names of the above three works, and most of the works mentioned earlier, and also the following additional works :—

Graha Vinoda, Kavi Kalpalatā Ṭīkā, a commentary on Bhagavadṛta entitled Paramārthaprapā Bhaktiśata ; vedānta Śata Śloki Ṭīkā and a commentary on Amaru Śataka, named Śṛṃgāra Taranginī.

On the whole, it seems that Sūrya had been a very great scholar. He was fully justified in speaking of himself in his gaṇitāmṛtakūpikā as 'a worthy pilot on the ocean of mathematics, an expert in prosody, rhetorie and music, and can adopt in high-class literature.' In the work "Gaṇitāmṛta Kūpikā he makes the following statement about himself :—

"Ahaṃ Sūryābhidhānaḥ Kaviḥ swhpradnyāpariṇāmataḥ Līlāvatīṃ vyākhyātuṃ vihitādarosmi".

*Miscellaneous Essays, 2nd edition, Vol. II, p. 251. I have stated on page 144, on the basis of Colebrooke's statement, that Sūryadāsa's commentary on Līlāvatī belongs to Śaka 1460. But that is a mistake. I got the correct information, about Sūryadāsa after that page was printed. The Śaka should be 1463.

Translation :—

"I, Sūryadāsa, have ventured to write a commentary on Līlāvati, on the strength of the intellectual power possessed by me." He further adds,

निर्मथ्य बीजगणितार्णवमात्मयत्नात्सद्वासनामृतमवाप्रमिदं मया यत् ॥
तत्संग्रहाय गणितार्णवकूपिकेयं टीका विरच्यत इहावनिदेवतुष्टयै ॥

At the beginning of his commentary of Bija, he remarks.

यत्पादांबुरुहप्रसादकणिकासंजातबोधादहं पाटीकुट्टकबीजतंत्रगहनाकूपारपारंगमः ॥
छंदोलंकृतिकाव्यनाटकमह (?) संगीतशास्त्रार्थवित्
तं वंदे निजतातमुत्तमगुणं श्रीज्ञानराजं गुरुं ॥ २ ॥

Still, at the end he observes,

तत्सूनुः (ज्ञानराजसूनुः) सूर्यदास, सुजनविधिविदां प्रीतये बीजभाष्यं ॥
चक्रे सूर्यप्रकाशं स्वमतिपरिचयादादितः सोपपत्ति ॥ ३ ॥

It appears from this that though he acquired knowledge from his father Jñānarāja, his work was mainly the outcome of his own intellectual wealth.

ANANTA—1447

He compiled 'Anantasudhārasa', a work on the calculation of the *Pañcānga*, in Śaka 1447. It follows the *Sūryasiddhānta*. Ananta remarks in the beginning.

ढुंढिविनायकचरणद्वंद्वं मुदमादधन् नत्वा ॥ सूक्ष्मानंतरसाख्यं तनुते श्रीकांतजोऽनंतः ॥

From this, the name of his father appears to be Śrīkānta. The author has not seen the work himself. He has stated this from (the information given in) the Gaṇakataranginī by Sudhākara. Sudhākara says that it was a work consisting of tables and that, Nārāyana was the author of Muhūrta-mārtaṇḍa, his father's name was Ananta, and Ananta's father's name was Hari (see the account of Gangādhara, Śaka 1502, given later on) and Śrīkānta, the name of the father of this Ananta, also is an epithet of Hari, and the dates of both of them appear to agree. From this, he (Ananta) seems to have been the father of the author of Muhūrta Mārtaṇḍa. But there is a commentary, Sudhārasakaraṇacaṣaka, on Ananta's 'Sudhārasa', by Ḍhuṇḍhirāja, and according to Aufrecht's catalogue, a part of this work called *grahaṇodaya* is in the library of the Sanskrit Pāthaśālā at vārānasī.

From this it appears that this is a karaṇa work containing tables useful for Pañcānga calculation. An account of the family occurs at 2 or 3 places in the works compited by Nārāyaṇa, the author of Muhūrtamārtaṇḍa, and by Gangādhara, his son (Page 150. It is mentioned every where that Hari is the name of Ananta's father and not Śrikānta. They give much information about Ananta but nothing about his works. This leads the author to doubt if this Ananta was really the father of the author of Muhūrtamārtaṇḍa.

ḌHUṆḌHIRĀJA

From the family history given by him in his work, Jātakābharaṇa, and by his son Gaṇeśa in his work 'Tājikabhūṣaṇa', it becomes evident that he was the resident of Pārthapur (Pātharī), situated to the north of Godāvari, near Devagirī (Daulatābād). He has stated Nṛsiṃha to be his father's name. The author has, on the basis of the genealogical table sent by Kāśīnātha Śāstrī, recorded him as the son of one Nṛsiṃha whose name appears in the genealogical tree, printed on page 140 in his account of Jñānarāja. From this, Ḍhuṇḍhirāja would be the uncle of Jñānarāja, the author of the *Sundara Siddhānta*. But Ḍhuṇḍhirāja has offered salutations to the preceptor Jñānarāja at the beginning of his work *Jātakābharaṇa*. This leads one to suspect that Jñānarāja, his preceptor, might have been different from the author of Siddhānta sundara, or else, Ḍhuṇḍhirāja might have been the son of some other Nṛsiṃha of the same family. Ḍhuṇḍhirāja has written a commentary 'Sudhārasakaraṇacaṣaka', on Sudhārasa, a karaṇa work, by Ananta ; similarly, according to Aufrecht Catalogue, the works, *Grahalāghava-Udāharaṇa*, *Graha-phalopapatti*, *Pañcāngaphala*, and *Kuṇḍakalpalatā*, were compiled by him. If this Ḍhuṇḍhirāja be the same person as Ḍhuṇḍhirāja, the author of the *Jātakābharaṇa*, his date must have been later than Śaka 1447. Viśvanātha (Śaka 1551) has referred* to the *Tājikabhūṣaṇa* by Gaṇeśa, son of the author of the *Jātakābharaṇa*. It follows from this that the date of compilation of the *Jātakābharaṇa* must have been earlier than Śaka 1500**.

Ḍhuṇḍhirāja's work *Jātakābharaṇa*, is very famous and it is now printed. It appears from the *Jātakābharaṇa* that Ḍhuṇḍhirāja's uncle compiled a work on astrology. The nam e of this uncle and that of his work are not known. Gaṇeśa's work, *Tājikabhūṣaṇa*, is also well known. It is recorded in Aufrecht's Catalogue that Gaṇeśa had another work, *Gaṇita Manjarī* to his credit.

---

*Viśvanātha-remarks in his commentary on the *Tājika Nīlakaṇṭhī* that the statement of the author of *Tājikabhūṣaṇa* viz. "Janmakālanalinī............" is wrong ; and this view is correct.

**Further information was received from Kāśīnātha Śāstrī after 272 pages of the book were printed. Its summary is given below !—

"Ḍhuṇḍhirāja carried on his studies under the care of Jñānarāja himself. The Śaka years of birth and death of the descendants, beginning from Sūrya are as follows :— Sūrya 1429-1510 ; Nāganātha 1480-1537 ; Gopāla 1545-90 ; Jñānarāja, bitrh year 1595 ; Rāma's death 1731 ; Vijñāneśvarī 1712-1769 ; Puruṣottama 1748-1799 ; Kāśīnātha, birth year, 1768. Nāganātha the son of Sūrya had received the title 'Raṇaśūra' from the Delhi Court. He compiled the work, entitled 'Narapatijayācārya,' Kāśīnātha Śāstrī received the title Sūricūḍāmaṇi in Śaka 1813 "Instances are found in which the uncle is younger than the nephew ; and hence it is not impossible that Ḍhuṇḍhirāja studied under the care of Jñānarāja and in that case the date of compilation of Jātakābharaṇa would come to somewhere between Śaka 1430 and 1460 and that of Tājikabhūṣaṇa Śaka 1480. Nāganātha whose name written below that of Sūrya in the genealogical table was Sūrya's son ; Gopālaand Jñānarāja are different persons, and there night have been one person each between Nāganātha and Gopāla and Gopāla and Jñānaraja (Otherwise, their date may be wrong). The author' is not quite sure that the above-mentioned Śaka years are quite reliable. But in the absence of the correct dates he has notedthem here for what they are worth. Nāganātha may have received the title of 'Raṇaśūra' in the reign of Akbar or Jehangir. There is an ancient work, entitlew Narapatijayācārya, written in Śaka 1097 and hence, I have presumed that Nāgnātha wrote a commentary on Narapatijayācārya, but it is not known if Nāganātha had actually written an independent work of the same title.

ANANTA

Ananta wrote a commentary on '*Kāmadhenu*', a work devoted to the calculation of tithi and other parts of the almanac ; and Ananta has written a commentary on it. The work, Kāmadhenu, was compiled in Śaka 1279 by Mahādeva, son of Bopadeva, a resident of Tryambaka on the bank of Godāvarī. It contains tables for calculating tithis etc. according to Brahmapakṣa and Āryapakṣa. The sons of this Ananta namely Nīlkaṇṭha and Rāma, compiled works in Śaka 1509 and 1512 respectively. From this, the date of Ananta's commentary on Kāmadhenu comes to about Śaka 1480. The Jātakapaddhati is an astrological work written by Ananta*.

FAMILY HISTORY

Rāma, the son of Ananta has recorded his family history in the conclusion of his work, *Muhūrta Cintāmaṇi*, as follows :—

आसीद्धर्मपुरे षडंगनिगमाध्येतृद्विजैर्मंडिते । ज्योतिर्वित्तिलकः फणींद्ररचिते भाष्ये कृतातिश्रमः ।।
तत्रावृत्त तत्तज्जातकसंहितागणितकृन्मान्यो महाभूभुजां । तर्कालंकृतिवेदवाक्यविलसद्बुद्धिः
स चिंतामणिः ।। ८ ।।

ज्योतिर्विदगणवंदिताङ्घ्रिकमलस्तत्सूनुरासीत् कृती नाम्मानंत इति प्रथामधिगतो भूमंडलाहस्करः ।।
यो रम्यां जनिपद्धतिं समकरोद्दुष्टाशयध्वंसिनीं ।। टीकां चोत्तमकामधेनुगणितेऽकार्षीत्सतांप्रीतये ।।
तदात्मज उदारधी बिबुधनीलकंठानुजो । गणेशपदपंकजं हृदि निधाय रामाभिधः ।।
गिरीशनगरे वरे भुजभुजेषुचंद्रमिते १४२२ । शके विनिरमादिमं खलु मुहूर्तचिंतामणिं ।। १० ।।

The author is giving his genealogical table below on the basis of this account and from the history given by his descendants in their works. His gotra was Gārgya. He was a resident of Dharmapurī, in Bidarbha, in the valley of the Godāvarī. Ananta left the place for Vārānasī where he resided. His descendants also used to reside at Vārānasī.

Cintāmaṇi (Gārgya Gotra)

Ananta (Padmā his wife)

Nīlkaṇṭha (Candrikā his wife) Śaka 1509 — Rāma, (Śaka 1512, 1522)

Govinda (Gomatī his wife)
Birth Śaka 1491

Mādhava
Śaka (1555)

* The author has not seen Ananta's works but he has described his work on the basis of the accounts given by his descendants and the *Gaṇaka Taraṅgiṇī* by Sudhākara.

History of Descendants

From the account given by Rāma and Nilkāntha, Cintāmaṇi appears to have been an astronomer and a great scholar. Ananta's account has already been given above.

The name of Nīlkanṭha's mother was Padmā. He has compiled a work entitled *Toḍarānanda*. Descriptions of this work occur in other works, from which it appears that the work contained all the three branches of astronomy, Gaṇita, Muhūrta and Horā : and even Mādhava, the grandson of Nīlkanṭha has supported this surmise. The author of *pīyūṣadhārā* (commentary) writes that it treats the risings and settingsof planets in the chapter Candravāravilāsa and deals with Nyūnādhimāsa (suppressed and intercalary months) in the chapter called Kālaśuddhīsaukhya. The author has seen a part of the book (No. 5088 in the Ānandāśrama) ; which contained only the section on Muhūrta. It contains a large collection of excerpts from earlier writers. The number of verses in the portion seen by him is about 1000 ; it contains a chapter on pilgrimage only and that too is incomplete. It appears, therefore, that the work must have been very voluminous. It may have received the name Toḍarānanda after Toḍarmalla, the minister of Akbar. Nīlkānṭha was a great follower of Mīmānsā and a scholar of *Sāṃkhya* Śāstra and as described by his son Govinda, was Paṇḍitendra, (the leader of Pandits) at the court of Emperor Akbar. Nilkāntha compiled a work *Samātantra*, (Varṣatantra), on Tājik which is also known as *Tāika Nīlkānṭhi*. The work is very famous and has been published along with different commentaries. Nilkāntha compiled it in Śaka 1509. Viśvanātha has written a commentary on it with examples. It belongs to Śaka 1557. The Aufrecht catalogue mentions the following additional commentaries on it :—

The Dwighaṭīkā, another by Lakṣmīpati and the third entitled the Śrīphala cardhini by Śrī Harṣa. Other commentaries have been described below. Nīlkantha has compiled a Jātakapaddhati, which contains 60 verses. Accordding to the author of the *Gaṇakataranginī*, the system (embodied in this work) is well known in the provine of Mithilā. According to Aufrecht Catalogue, Nīlkanṭha has compiled the following astronomical and astrological works :—

Tithi Ratnamālā ; a work on Horāry astrology entitled *Praśna Kaumudī* or Jyotiṣa Kaumudī ; Daivajña vallabhya and a commentary or Jaimini Sūtra called Subodhini. From the same catalogue it appears that Nīlkanṭha also wrote commentaries on Graha Kautuka, Graha Lāghava, Makaranda and on a Muhūrta work.

The account of Rāma will follow later. Govinda, Nīlkanṭha's son, has written Pīyūṣadhārā, a commentary on Muhūrtacintāmaṇi. It is very extensive and famous. He compiled it at Vārānasī. In that work he states that Mātṛpur, in Vidarbha, was his place of residence. Perhaps, Dharmapur itself may have Mātāpur as its second name. Govinda was born in Śaka 1491. His mother's name was Candrikā. He wrote the commentary, Pīyūṣadhārā, in Śaka 1525. He also wrote the commentary, Rasālā, on Tājika Nīlkanṭhi. It was written in Śaka 1544. The commentary, Pīyūṣadhārā, reveals great ingenuity on the part of Govinda. But while in his commentary on the 9th verse in the chapter on Saṃkrānti, he observes, "Eclipses are falsified if one follow the Sāyana system of calculation. A

computed from Brahma Siddhānta, together with the corrections mentioned by the *Rājamṛgāṅka*. The work describes only the method of finding the true places of planets. The total number of verses (in it) is 46. It appears that the works used to be accompanied by tables ; but they were not found in the copy seen by the author. But one cannot do any calculation without such tables. The writer calls this work *Laghu Kheṭaka Siddhi* which indicates that he may have written another work called *Bṛhat Kheṭaka Siddhi*. Some verses attributed to Dinakara are given in the commentary on the *Mahādevi Sāraṇī*, but they are not found in this work. This also lends support to the surmise about the existence of a larger work. The writer has given his own account in the words.

श्रीमदगोत्रे कौशिके साग्निकोभूद् दाक्षोयं ज्ञातिमोढप्रसूनः ॥
जातो ग्रामे साभ्रमत्याः समीपे वारेजाख्ये विप्रवर्याश्रिते च ॥ ३१ ॥
तत्पुत्रजो दिनकरः सकलानि खेटकर्माणि वीक्ष्य नततं हि सवासनानि ॥
चक्रे शके खखतिथि १५०० प्रमिते च संवत् पंचाग्निंभूपति १६३५ मिते लघुखेटसिद्धिं ॥ ३२ ॥

The *Candrārkī* consists of only 33 verses and deals only with the calculation of the true places of the sun and moon.

This work also takes Śaka 1500 as its epochal year. It appears that the work may have been accompanied by tables giving the equation of centre for finding the true place of the sun and moon ; and then these are to be used for calculating tithi and other parts. From this it appears that the *Laghu Cintāmaṇi* tables of Gaṇeśa Daivajñya were not in use in Gujerat in those days.

A correction stated to be in use in Gujerat is mentioned in both the works. The same correction is found also in the *Graha Cintāmaṇi* to be described (on page 151) later, and in the commentary on the *Mahādevī Sāraṇī* at some places, it is called 'Rāmabīja'.

GAṄGĀDHARA (Śaka 1508)

Ananta
Kṛṣṇa
Hari
Ananta
Nārāyaṇa
Gaṅgādhara

In Śaka 1508 he wrote Manoramā, a commentary on Graha Lāghava. He was the son of Nārāyaṇa, the author of Muhūrta Mārtaṇḍa. The genealogical table, given in the margin, is based on the information given by both the authors. The *Muhūrta Mārtaṇḍa*, was compiled in Śaka 1493, and the author has given in it his family history. From this it is learnt that he was a Vājasaneyī Brāhmaṇa belongingto Kauśika gotra. He was a resident of Ṭāpar, a village situated to the north of the famous temple of Śiva (Ghṛṣṇeśvara) which lies to the north of Devagiri (Daulatabād), and his ancestors were originally residents of Sāsamaṇūr. There is a village, Verul, situated about 4 miles from Daulatābād, and the deity there is at present known as Ghṛṣṇeśvara. Janārdana Hari Āṭalye has published the *Muhūrta Mārtaṇḍa* along with its Marāṭhī translation. He writes in its introduction that, on enquiry at the village Ṭāpar and its neighbourhood, he came to know that the descendants of the family of his meternal uncle only are now surviving.

RĀMABHAṬA (Śaka 1512)

He has written a karaṇa work entitled Rāmavincda. It has adopted Śaka 1512 as the epochal year, and the length of the year, the epochal positions and motions of planets, are based on the modern Sūrya Siddhānta. The corrections to be applied to planets' motions are the same as those mentioned before (page 45) Under orders o f Śrī Mahārāja Rāmadāsa, a minister of Akbar, Rāma Bhaṭa compiled* the Rāmavinoda in year 35 of the Akbar era 35 (*i.e.* Śālivahana Śaka 1512). It contains 11 chapters and 280 verses. Viśvanātha has written an illustrative commentary on it. Rāma has compiled a small volume of tables devoted to the calculation of tithi's etc., containing 17 verses, which form a part of the work ; and Sudhākara Dwivedī says, that people on Jaipur side compile their almanacs with the help of this work.

His well-known work Muhūrta Cintāmaṇi was written in Śaka 1522. It was compiled at Vārānasī. The author himself has written a commentary on it entitled 'Pramitākṣarā. In addition to this there is the famous commentary, Pīyūṣadhārā, on it, written by his nephew Govinda. Both these commentaries have been printed.

His family history has already been given (page 147) under the account of Ananta.

ŚRĪNĀTHA (Śaka 1512)

He wrote a Karaṇa work, named *Graha Cintāmaṇi* in Śaka 1512. It describes the method of calculating planets' places from 'Vaiṣagaṇa'. The work appears to have been accompanied by tables. They were not found along with the copy seen (Deccan College Collection No. 304 of 1882-83). The work is of no use without them. The work neither gives any epochal positions nor any clue to ascertain the school (pakṣa) to which it belongs. The work has two chapters and even includes the section on astrology. The name of Śrīnātha's father, was Rāma** and that of his elder brother, Raghunātha.

VIṢṆU

There is a well-known village named Pātharī in Bidarbha. It has already been described on page 141. There is a village Golāgrāma, near the northern bank of the river Godāvarī and 2½ yojanas (about 20 miles) to its west. A very well-known family of scholars lived in that village. The family shifted to Vārānasī later on. It produced a number of authors and Viṣṇu was one of them.

He compiled a Karaṇa work. It has adopted Śaka 1530 as the epochal year; it belongs to Saurapakṣa. He has in addition written a commentary named *Subodhinī* on the Bṛhat *Cintāmanī by*Gaṇeśa Daivajñya, the author of the *Graha Lāghava*. It explains the theory also. The study of such commentaries proves very useful for the compilers of new works on astronomy. His brother Viśvanātha has written an 'Udāharaṇa' on his Karaṇa work. In his *Muhūrta cudāmaṇi*, Śiva informs that Viṣṇu was the 'Jagatguru' (world teacher). In

* According to Dr. Bhāṇḍārkar (*Report on the search for Sanskrit Manuscript* 1883-84, Page 84) it was compiled in Śaka 1535 ; but that is an error.

**Prof. Bhāṇḍārkar remarks that this Rāma may probably be the same as Rāma, the author of Muhūrta Cintāmaṇi (Report on the search for Sanskrit Manuscript 1882-83, page 88). But the account of Rāma, the author of the *Muhūrta Cintāmaṇi* , given above, will show that it is an impossibility.

addition to this, some more account of the author will be found in the following verses by Viśvanātha.

The famous commentator Viśvanātha, and Kamalākara, the author of Siddhānta tattva were born in this very family. The following verses appear in a detailed account of his family given by Kamalākara :—

अथात्र सार्धबिरदस्र २०।३० संख्यपलांशकैरस्ति च दक्षिणस्यां ।।
गोदावरीसौम्यविभागसंस्थं दुर्गं च यद्देवगिरीति नाम्ना ।। १ ।।
प्रसिद्धमस्मान्नृप १६ योजनैः प्राग्याम्यांतराशास्थितपाथरी च ।।
विदर्भदेशांतरगास्ति रम्या राज्ञां पुरी तद्गनदेशमध्ये ।। २ ।।
तस्यास्तु किंचित्परभाग एव सार्धद्वि २ ।। तुल्यैः किल योजनैश्च ।।
गोदावरीवर्ति सदैव गंगा या गौतमप्रार्थनया प्रसिद्धा ।। ३ ।।
अस्याः सतां सौम्यतटोपकंटे ग्रामोस्ति गोलाभिधया प्रसिद्धः ।।
तथैव याम्ये पुरुषोत्तमाख्या पुरी तयोरन्तरगा स्वयं सा ।। ४ ।।
गोदावरीसौम्यतटोपकंठगोलाख्यसद्ग्रामसुसिद्धभूमौ ।।
विप्रो महाराष्ट्र इति प्रसिद्धो रामो भरद्वाजकुलावतंसः ।। ७ ।।
बभूव तज्जोखिलमान्यभट्टाचार्योतिशास्त्रे निपुणः पवित्रः ।।
सदा मुदा सेवितभर्गसूनुर्दिवाकरतत्तनयो बभूव ।। ८ ।।

Translation :—

(1) On the northern bank of Godāvari is situated the fortified town called Devagirī, whose latitude is 20°-30′.

(2) The city of Pātharī, which is 16 yojanas from this town and in S.E. direction is the capital of Vidarbha and is situated in the middle of the country.

(3) At a place, a little West to this city and about 2½ yojanas away, is a spot on the bank of the Godāvarī, where the river Ganges is regarded to have come to stay with the request of Gautama.

(4) On the northern side of this river there is a village named 'Gol' and on the southern side is a village named Puruṣottama, the river flows between the two.

(7) There lived in the village of Gol, on the northern bank of Godāvari, a Mahārāṣtriān Brāhmaṇa, named Rāma belonging to Bharadwāja gotra.

(8) His son, Bhaṭṭācārya became very famous as a scholar of astronomy and he (Bhaṭṭācārya) got a son, Divākara, by the favour of God Gaṇeśa whom he used to worship.

Rāma was an astronomer ; Bhaṭṭācārya was a follower of 'Mīmāṃsā and a logiciar. Divākara was a great astronomer and a disciple of Gaṇeśa Daivajñay, the author of the *Graha lāghava*. Such is the information that one can gather from the family history writter by Viśvanātha, Nṛsiṃha, Mallāri and other descendants of his family.

Divākara had five sons. Viśvar ātha has paid a fine tribute to their erudition and character in his commentary on Tājika Nilkanṭhi. Viśvanātha himself was the yourgest of the five. The description runs thus :—

दिवाकरो नाम बभूव विद्वान् दिवाकराभो गणितेषु मन्ये ।।
स्वकल्पितैर्येन निबंधवृंदैर्बतधंजगद्दर्शितविश्वरूपं ।। २ ।।

तस्यात्मजा: पंच समा बभूवु: पंचेंद्रकल्पा गणितागमेषु ।।
पंचानना वादिगजद्रभेदे पंचाग्निकल्पा द्विजकर्मणा च ।। ३ ।।
अजनिष्ट कृष्णनामा ज्येष्टस्तेषां कनिष्टानां ।।
विद्यानवद्यवाचां वेत्ता स स्याज्जगत्स्व्यात: ।। ४ ।।
तस्माज्यात: कनिष्टो विविधबुधगणात्खेष्टतां प्राप जाग्र-
ज्ज्योति:शास्त्रेण शश्वत्प्रकटितविभवो यस्य शिष्य: प्रशिष्य: ।।
विष्णुर्ज्योतिर्विदुर्वीपतिविदितगुणो भूमिदर्वीकरेंद्रो ।।
ग्रंथव्याख्यानखर्वीकृतविबुधगुरुर्गर्वहा गर्वभाजां ।। ५ ।।
आसीदासिंधुदासीकृतगणकगणग्रामणीगर्वभेत्ता ।।
नेता ग्रथांतराणां मतिगुरुरनुजस्तस्य कस्याप्यतेजा: ।।
मल्लारिर्वादिवृंदप्रशमनविधये कोपि मल्लारिनामा ।।
व्यक्ताव्यक्तप्रवक्ता जगति विशदयत्सर्वसिद्धांतवक्ता ।। ६ ।।
तस्यानुज: केशवनामधेयो ज्योतिर्विदानंदसमुद्रचंद्र: ।।
वाणीप्रवीणान्वचनामृतेन संजीवयामास कलाविलासी ।। ७ ।।
तस्यानुज: संप्रति विश्वनाथो विष्णुप्रसादादगुणमात्रविष्णु: ।।
सर्वज्ञदैवज्ञविलाससुज्ञात् नृसिंहत: साधितसर्वविद्य: ।। ८ ।।

Summarized translation :—*

(2) Divākara came to be regarded as an authority in astronomy, and was, like the 'diwākara' (sun) who envelopes the whole universe with his rays, described the construction of the universe by compiling various astronomical works.

(3) He had five sons, who were like five Indras in the subject of astronomy, or like five lions defeating the opponents or like five sacred fires on account of their pious behaviour.

(4) He gave birth to Kṛṣṇa, the eldest of the fives who became famous because of his faultless knowledge.

(5) The next son born, was Viṣṇu, who had attained such superiority of intellect, that his disciples, along with their disciples, could defeat their opponents in discussions on astronomical topics.

(6) The next son, Mallāri, became very famous because of his knowledge of arithmetic, algebra and mensuration.

(7) His younger brother, named Keśava, was still superior in so far as he compiled siddhānta works.

(8) His younger brother Viśvanātha, who got his education from Nṛsiṃha, became a scholar of all śāstras including astrology and astronomy.

* In translating these verses, the author) has omitted the translation of various lengthy poetic epithets used for the astronomers simply for the sake of composition, since these have nothing to do with the history of astronomy.

The following verses by Kamalākara which follow those given above state the history of this family as follows :—

अस्यार्यवर्यस्य दिवाकरस्य श्रीकृष्णदैवज्ञ इति प्रसिद्धः ।। ९ ।।
तज्जस्तु सदगोलविदां वरिष्टो नृसिहनामा गणकार्यवंद्यः ।। १० ।।
बभूव येनात्र च सौरभाष्यं शिरोमणेर्वार्तिकमुत्तमं हि ।।
स्वार्थं परार्थं च कृतंत्वपूर्वसद्युक्तियुक्तं ग्रहगोलतत्वं ।। ११ ।।
तज्जस्तु तस्यैव कृपालवेन स्वज्येष्टसद्बंधुदिवाकराख्यात् ।।
सांवत्सरार्यादगुरुत: प्रलब्धशास्त्रावबोधो गणकार्यतुष्टचै ।। १२ ।।
दृग्गोलज्ञक्षेत्रनवीनयुक्तचा पूर्वोक्तितत: श्रीकमलाकराख्य: ।।
समस्तसिद्धांतसुगोलतत्वविवेकसंज्ञं किल सौरतत्वं ।। १३ ।।
खनागपंचेदु १५८० शकेऽवतीते सिद्धांतमार्याभिमत समग्रं ।।
भागीरथीसौम्यतटोपकंठवाराणसीस्थो रचयांबभूव* ।। १४ ।।

Translation :—

(9 & 10) This talented Divākara had a famous son, the astronomer Śrīkṛṣṇa, who, in his turn gave birth to a son, Nṛsiṃha, who was well versed in the knowledge of the '*sphere*' and honoured by astronomers.

(10) He compiled a commentary on the Śiromaṇi, and one on the *Sūrya siddhānta* and a work explaining the sphere and motions of planets. (11 to 14) His (second) son Kamalākara who got his learning from his learned elder brother Divākara, who was his preceptor in the astrology, compiled the above mentioned works on astronomy, including the new theory of spherical areas. This work was intended to be a standard work, explaining all theories about 'gol and siddhānta and was named 'Siddhānta, tattvaviveka'. He compiled this siddhānta work in the Śaka year 1580, at Vārānasī which is situated on the northern bank of the river Bhāgirathi (Ganges).

The genealogical table prepared from this description and other information, is given below :—

Rama (A Mahārāṣṭra Brāhmaṇm of Bhāradvāj gotra and Taittiriya Branch).

Bhaṭṭācārya

Divākara

Kṛṣṇa Viṣṇu Mallāri Keśava Viśvanātha

Nṛsiṃa (Birth Śaka 1508) Śiva

Divākara (Birth Saka 1528) Kamalākara Gopināth Ranganāth

*Siddhānta Tattvaviveka, page 407/8, printed at Vārānasī by Sudhākarā Dvivedī,

Nṛsiṃha, the son of Kṛṣṇa has written in his commentary on the Sūrya Siddhānta that Kṛṣṇa, the eldest son of Divākara compiled a work on algebra in 'Sūtra' (aphoristic) form. The Muhūrta Cūḍamaṇi, a work by his son Śiva, and the works of Divākara, his grandson, go to show that he (Kṛṣṇa) was a seer, that he had received honours at the king's court and that he wrote works on other sciences also. According to Aufrecht Catalogue, Keśava, a son of Divākara and uncle of Nṛsiṃha, compiled a work entitled 'Jyotiṣamaṇimālā' in 1564 A.D. (Śaka 1486). He appears to be Keśava of this very family, as the name suggests, but his date does not agree with the established dates of Mallāri and Viśvanātha. A description of other persons of this family has been given further on.

Mallāri has stated that his family deity was Mallāri. In his commentary on Śiromaṇi, written in Śaka 1543, Nṛsiṃha states that Divākara died at Vārāṇasī. He was the direct disciple of Gaṇeśa Daivajña, and from this it seems that he must have been in South India till about Śaka 1500. The works compiled by the members of this family after Śaka 1533 were written at Vārāṇasī. From this it appears that this learned family shifted to Vārāṇasī within 25 to 30 years after Śaka 1500. None of them seems to have received actual patronage at the Delhi Court ; they are, however, described as being honoured by kings.

MALLĀRI

Mallāri was born in the famous family described by Viṣṇu above. He has written a commentary on the *Grahalagava*. He has described in it the date of this commentary in a strange way, thus :—

बाणो ५ नाच्छकत: कुगम ३१ विहृतान्मूलं हि मास: स ग्रक
बाणै ५ भं च दशोनितं १० दिनमितिस्तस्या दलं स्यात्तिथि: ।।
पक्ष: स्यात्तिथिसंमितोऽखिल*युति: सप्ताब्धितिथ्युन्मिता १५४७
बालाख्यो गणको लिलेख च तदा टीका परार्थं त्विमां ।।

Translation :—The astronomer, Bāla, wrote this commentary in the Śaka year, denoted by 1547 diminished by the sum of the numbers denoting the month, the nakṣatra, the day of the week, the lunar day, and the half month. The month was the number which is the square root of "the current śaka year reduced by 5 and divided by 31" *i.e.* $\sqrt{\frac{1524-5}{31}} = \sqrt{49} = 7$. The nakṣatra was equal to the month plus 5 *i.e.* 12th. The day of the week was equal to the nakṣatra reduced by 10, hence 2 or Monday ; the lunar day was the 1st and Pakṣa was the 1st"

From this it is proved that an astronomer named Bāla, wrote this commentary on Monday, the 1st lunar day of the bright half of Aśvin in Śaka 524, the nakṣatra being Uttarā. This must be the date of the commentary also, because it agrees with that of his brother Viśvanātha.

Mallāri has explained the theory of Grahalāghava in the commentary. The task of explaining the theory of a work like the *Grahalāghava* can be said to be even more difficult than that explaining the theory of a Siddhānta work. But they accompanished the work with great success.

* 1524 + 7 + 1 + 1 + 2 + 12 = 1547

Śaka + month + tithi + pakṣa + day of the week + nakṣatra.

VIŚVANĀTHA

He was a commentator like Bhaṭotpala. He was the son of Divākara of Golāgrāma. His family history can be found from the account given by Viṣṇu. He has recorded the date of his commentary on Tājakanīlkanṭhī, as below :—

चंद्रबाण शरचंद्र १५५१ संमिते हायने नृपतिशालिवाहने ।।
मार्गशीर्षसितपंचमीतिथौ विश्वनाथविदुषा समापितं ।।

Translation :—

"This was completed by Viśvanātha on the 5th lunar day of the bright half of Mārgaśirṣa in the year 1551 of the era of king Śālviāhaṇa."

The author has seen a number of commentaries on the Nīlkanṭhī, in many of these the above verse was missing ; it was found only in a few commentaries. It is an instance of how our people are indiffierent in the matter of specifying the dates of the compilation of their works. There is absolutely no doubt about this Śaka. It authentically becomes evident from the references at other places in the commentary. Viśvantāha has written commentaries, consisting of illustrative examples, on several works like the *Sūryasiddhānta*. For the main example in them he has adopted Śaka 1534 as the year, but has incidentally also, taken Śaka years 1530, 1532, 1542 and 1555. In the commentary on 'Pātasāraṇī', he has adopted Śaka 1553 as the year for his example. In the Keśavi-jātaka-paddhati, he has adopted for his example Śaka 1508. The birth horoscopes are cast with the help of the Jātakapaddhati. It would appear that Śaka 1508 may have been the date of birth of Viśvanātha and he appears to have compiled his works between the Śaka years 1534-56. In a line from his commentary on Grahalāghava, (already given on page 131) he calls Gaṇeśa Daivajñya his preceptor, but it is simply a matter of formality. It is like the remark by Dhanarāja, the commentator of the *Mahādevi Sāriṇī*, who in his commetary written in Śaka 1557, calls Mahādeva his preceptor, even though the *Mahādevi Sāriṇi* was compiled in Śaka 1238.

Kṛṣṇa śāstrī Goḍbole has given in the Grahalāghava three verses at the end which state that, in order to ensure agreement with observation, Viśvanātha has mentioned a correction to it 211 years after it was compiled. This means that the date of Viśvanātha comes to Śaka 1653. But it is quite evident from his family history and his works that the date of Viśvanātha, the commentator of the *Grahalāghava*, must be in the 16th century and not the 17th. The author has seen several editions of Viśvanātha's commentary on Grahalāghava, but they do not contain these three verses. Viśvanātha, referred to in them, must be a different person. Viśvanātha Davajñya Sangameśvarkara, the son of Gopāla compiled a work entitled Vratarāja at Vārānasī in śaka 1658. The above three verses may have been compiled by this Viśnanātha.

HIS WORKS

Viśvanātha has written the following commentaries containing examples:—

(1) The *Gahanārtha Prakāśikā* Ṭīkā on the Sūrya Siddhānta. In this, Viśvanātha writes, "I am elucidating the Sūrya Śiddhānta, the commentary by Nṛsiṃha may be consulted for its theory". Nṛsiṃha wrote his 'Saurabhāṣya-commentary in Śaka 1533. From this it is evident that Viśvanātha wrote his

Udāharaṇa on the Sūrya Siddhānta after that date. The number of verses in it is 5000. (2) Siddhāntaśiromaṇi* (3) Karaṇa Kutūhala (4) Makaranda (5) Grahalāghava (6) Pātasāraṇī by Gaṇeśa Daivajñya (7) Anantasudhārasa* (8) Rāma Vinodakaraṇa* (9) the Karaṇa work by his brother Viṣṇu* (10) Keśavi Jātakapaddhati (11) Samātantraprakāśikā on Tājaka-Nīlkanṭhi. This belongs to śaka 1551. The Aufrecht's Catalogue has mentioned the following additional commentaries on :—(12) Somasiddhānta (13) Tithi Cintāmaṇi (14) Candramānatantra (15) Bṛhajjātaka (16) Śrīpatipaddhati (17) Vasiṣṭhasaṃhitā (18) Bṛhatsaṃhitā.

Viśvanātha has added solved examples in the commentaries and hence those commentaries are very useful for the student. Kṛṣṇa Śāstrī Goḍbole has published a Marāṭhī edition of Grahalāghava containing solved examples, which is for the most part, a translation of the Viśvanāthī commentary.

Viśvanātha has not given any theory in his commentary ; still the fact that he had a good knowledge of the astronomical science is evident from his works. He compiled all his works at Vārānasī.

NṚSIṂHA (Birth date 1508)

He was the son of Kṛṣṇa who was the eldest son of Divākara of Golāgrāma (page 154). He was born in Śaka 1508. He was guided in his studies biy his uncles Viṣṇu and Mallāri. He wrote a commentary on the Sūrya Siddhānta entitled Saurabhāṣya in Śaka 1533. It explains the theory and contains 4200 verses. His commentary on the Siddhānta Śiromaṇī named Vāsanā Vārtika was written in Śaka 1543. It was also called Vāsanā-Kalpalatā and the number of verses in it is 5500. From both these commentaries it seems that he had a sound knowledge of astronomy. His son Divākara has written that he was very proficient in Mīmāṃsā.

ŚIVA

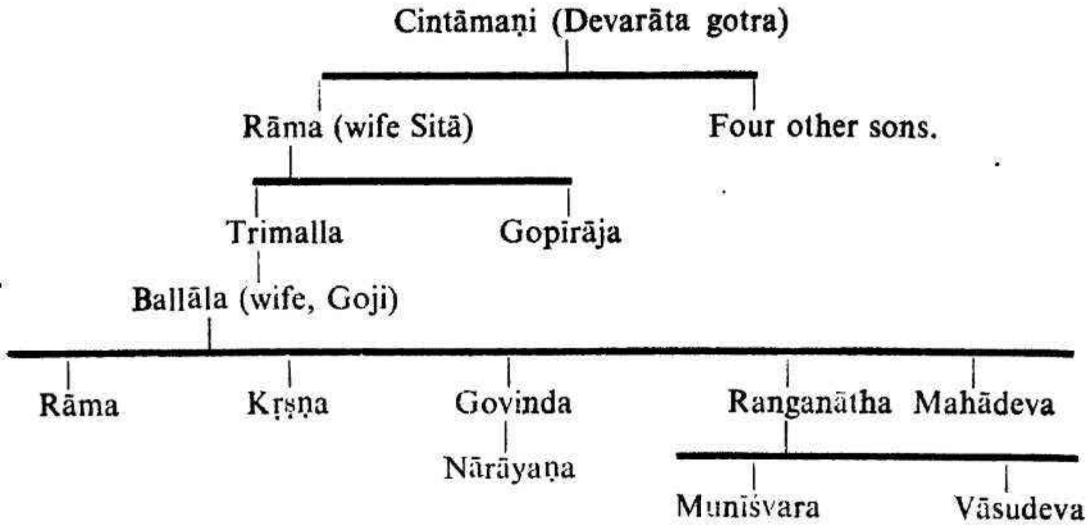
Born in the family described in the author's account of Viṣṇu (P. 154), Śiva was the brother of Nṛsiṃha and son of Kṛṣṇa. His birth year may have been Śaka 1510. Sudhākara states that he had written a commentary on Ananta Sudhārasa. He has compiled a muhūrta work named Muhūrta Cūḍāmaṇi. Divākara, his nephew and disciple, has rwritten ih his work Jātakapaddhati, that he was a 'jagatguru' (world teacher).

According to Sudhākara, there was another Śiva, son of Rāma Daivajñya, who wrote a work entitled Janmacintāmaṇi.

KṚṢṆA

He was born in a well-known family of scholars. The genealogical table below has been prepared from the family history given by the writers born in this family.

* The author has not seen these four commentaries himself. He has given the names from the *Gaṇakataraṅgiṇī*.



PLACE

Cintāmaṇi, a Yajurvedī Brāhmaṇa, used to reside in Dadhigrāma, a village on the Bank of Payoṣṇī in vidarbha. The position of this village has been described by Munīśvara at the end of his Marīci commentary in the line,

एलिचपुरसमदेशे तटे पयोष्ण्या शुभ दधिग्रामे ॥

meaning "In the auspicious (Village of) Dadhigrāma, situated on the bank of Payoṣṇī, in the same latitude as Ellicpur".

The *Palabhā* of Dadhigrāma, mentioned in commentary on the Keśavi Jātaka written by Nārayaṇa, son of Govinda, is 4-30, from which the latitude of the 'place would come to be 21°-15'. This is also the latitude of Ellicpur. It appears, thereofore, that Dahigāon must be a village situated to the east or west of Ellicpur, in the same latitude.*

Ballāla went to Vārānasi to reside there permanently. His descendants, as it appears from their works, continued to reside at Vārānasī. However, it appears from Nārāyaṇa's commentry on Keśava's *Jātakapaddhati* that he compiled it at Dadhigrāma.

HISTORY OF ANCESTORS

Kṛṣṇa and Munīśvara have wirtten in their works that Rāma possessed such a wonderful prophetic faculty that the King of Vidarbhas always obeyed him. The date of Rāma, as reckoned from those of Kṛṣṇa and Munīśvara appears to be about Śaka 1440. When the Bahamaṇī kingdom was split into five parts about 1500 A. D. (Śaka 1422), one of the parts was transformed into the Kingdom of Berar (Vidarbha) with Ellicpur as its capital. As Rāma is said to have been the adviser of the King of Vidarbha, he must have been residing at Ellicpur. Ballāla was a great devotee of Rudra (Śiva). Ranganātha has stated in his commentary on the Sūrya Siddhānta that Rāma, the eldest

*By the formula tan. lat.=*Palabhā* ÷ 12, the given *palabhā* 4/30 would indicate 20°34' (not 21°15') as the latitude of the place. (R.V.V.)

son of Ballāla compiled a theory work to explain the 'Anantasudhākara.' This may be the same as the *Sudhārasa* of Ananta referred to on page 145. This Rāma also was a great devotee of Śiva ; and, according to the Marīci commentary, he was alive in Śaka 1557, the date of that commentary.

KṚṢṆA HIMSELF

Kṛṣṇa was the second son of Ballāla. He wrote a commentary work, Bīja navānkura, on Bhāskarācārya's 'Bījagaṇita'. The commentary has also received Bījapallava, "Kalpalatāvatāra," as additional names. Kṛṣṇa has suggested in it some new artifices of his own. The commentary has proved to be the best of the ancient commentaries and is recognized as such by learned men. In this commentary, he calls himself a disciple of Viṣṇu who was the disciple of Nṛsiṃha, the nephew of Gaṇeśa, the author of the *Grahalāghava*. It is not known if this Viṣṇu was the same as the Viṣṇu of Golāgrāma (page 154.). The dates of both of them appear to be almost the same. Kṛṣṇa has written a commentary, consisting mainly of examples, on the Jātakapaddhati of Śrīpati. He has adopted in it Śaka 1478, the birth Saka of Khānkhān, the minister, by way of example in it. There was no possibility of Khānkhān to be a minister before Saka 1500. Ranganātha has referred to both these commentaries by Kṛṣṇa in his commentary on the Sūryasiddhānta, and he also writes there that Kṛṣṇa was held in high esteem at the court of Emperor Jehangir. Jehangir ruled from Śaka 1527 to 1549. From this, Kṛṣṇa appears to have compiled, both the commentaries during the period Śaka 1500 to 1530. He has written another work "Chādaka Nirṇaya", which had been published by Sudhākara Dvivedī. It appers from the commentary, Marīci that he had won the affection of Nuruddin, a Muslim officer, and that he was not living in Śaka 1557.

DESCENDANTS

Nārāyaṇa, son of Govinda, has written a commentary on Keśava's Jātakapaddhati, in which he has adopted Śaka 1509 for the purpose of illustrative examples. There is a work on algebra, named Nārāyaṇīya Bīja consisting of aphorisms in Ārya metre. The author of the *Gaṇaka Taraṅgiṇī* says that it may have been compiled by Nārāyaṇa. Furthermore, this Nārāyaṇa may be identical with Nārāyaṇa, the guru of Munīśvara.

RANGANĀTHA

An account of his family has already been given while describing Kṛṣṇa's family. He wrote a commentary, Gūḍhārtha Prakāśikā, on the Sūrya Siddhānta. A detailed description of it has already been given. He has given in the commentary itself, the date of its compilation in the following verse :—

शके तत्वतिथ्युन्मिते १५२५ चैत्रमासे सिते शंभुतिथ्यां बुधेर्कोदयान्मे ।
दलाढयद्विनाराचनाडीषु ५२।३० जातौ मुनीशार्कसिद्धांतगूढप्रकाशौ ॥

Translation :—(not necessary)

Ranganātha says that his son Munīśvara, and the commentary Gūḍhārtha prakāśikā, both appeared 52½ ghaṭis after sunrise, on Wednesday, the "Śivatithi of the bright (or dark) half of Caitra in Śaka 1525 ; and it is written in the same

commentary that Kṛṣṇa was honoured by the Emperor Jehangir. Jehangir began to rule since Śaka 1527 and not before. Hence, this śaka appears doubtful. But Munīśvara's works belong to Śaka 1557, 1568 and 1572. This means that the above Śaka is not quite improbable. Ranganātha might have began writing his commentary in Śaka 1525. The '*ekādaśī*' day in the "śukla or Kṛṣṇa pakṣa" of the elapsed Śaka year 1525, could not be a Wednesday. The Śukla Caturdaśī fell on Wednesday and lasted for 10 ghaṭis. This would agree with the particulars in the quotation if *śivatithi* is taken to mean Caturdaśī. Otherwise, the Wednesday must be the 'daśamī, day in Caitra Kṛṣṇa pakṣa of Śaka 1524 which lasted for 8 ghaṭis. Hence, complete agreement is reached if 1525 be taken as the current śaka (*i.e.* elapsed Śaka 1524), the dark half as the pakṣa, and Ekādaśī as the Śivatithi. In short, Ranganātha was alive in Śaka 1525, but not in Śaka 1557, as is apparent from the Marīci commentary.

His commentary on the Sūrya Siddhānta shows that Ranganātha had a sound knowledge of astronomy, particularly that of Bhāskara's Siddhānta. He has explained the theory, throughout the commentary. It also appears from the commentary that he taught students with the help of astronomical instruments, like the celestial globe, which he had constructed himself. He wrote the commentary at Vārānasī.

GRAHA PRABODHA, Śaka 1541

This is a Karaṇa work, its epochal year being Śaka 1541. It consists of 38 verses in all, and they deal with only the question of the true places of planets. The treatment of this subject, the method of calculating ahargaṇa, eleven years' cycle, etc. are all on the lines of the *Grahalāghava*. The author writes in the colophon :

आसीत् गार्य (? र्ग्य) कुलैकभूषणमणिर्विद्वज्जनानंदकृत
शिष्याज्ञानतमोनिवारणरविर्भूमीपतिप्रार्थितः ।।
ज्योतिःशास्त्रमहाभिमानमहिमास्पष्टीकृतब्रह्मधी-
धैर्योदार्यनिधिस्तुकेश्वर इति ख्यातो महीमंडले ।। ३६ ।।
तदात्मजस्तच्चरणैकभक्तिस्तद्वत्प्रसिद्धः शिवनामधेयः ।।
तदंगजो दृग्गणितानुसारे ग्रहप्रबोधं व्यतनोच्च नागः ।। ३७ ।।

Translation :—

(36) There was a Brāhmaṇa, named Tukeśvara, who was an ornament for the Gāryya, (Gārgya ?) family, who gave joy to learned men, who was the 'sun' competent to remove the darkness of ignorance among his pupils, who was honoured by the king, who was very famous in the world as one who explains the astronomical theory and one who was courageous and broadminded.

(37) His son, named Śiva, who was devoted to him, was equally famous. The latter's son, Nāga, compiled this work on planetary calculation, agreeing with observation.

It appears that the author's name was Nāgeśa, his father's name was Śiva and that of his grandfather, Tukeśvara. It is doubtful how far his description of Śiva and Tukeśvara was true ; but so far as his claim to having compiled a work agreeing with observation goes, the work is hopeless. He has not

The sum of all these numbers (8+1+3+1+13) i.e. 26 increased by 13 and multiplied by 40 would give the year (=1560) of completion of the work.

These verses show that the commentary (first half) was completed on Sunday, the 3rd lunar day of the bright half of Āṣāḍha in Śaka 1557, the nakṣatra being Puṣya and yoga being 'Vyāghāta'. The latter half was completed in Śaka 1560.

Sudhākara says that the Siddhānta-sārvabhauma was completed in Śaka 1568, and the author's own commentary on it was completed in Śaka 1572. The Marici commentary is a voluminous work and the number of verses in it being 25000. It contains a very large collection of quotations from ancient authors. The commentary on Līlāvatī contains 7000 verses and has won recognition from scholars. The commentary on the first half of the Sārvabhauma siddhānta contains 8000 verses. It is seen at several places in his works that he was a staunch admirer of Bhāskarācārya. The length of the year, the number of revolutions of planets and other measures adopted in the Śārvabhauma-Siddhānta are the same as in the Sūrya -Siddhānta.

Munīśvara was also known by another name, Viśvarupa. He writes in his commentary, Marīci, that he obtained knowledge through the favour of Kārtikswāmī. He states that, Kṛṣṇa's disciple Nārāyaṇa was his guru. Both of them probably belonged to the same family. His works show that he may have obtained the patronage of Emperor Śāhājahān. In his Sārvabhauma Siddhānta, he has recorded the year of the Hijrī era and the date and time of the coronation of Emperor Śāhājahān, and also the horoscope of the moment. From this we come to know that Śāhājahān was crowned on Monday, the 4th February, 1628 A. D., the 10th lunar day of Māgha Śukla, of Śaka 1549, (the year 1037 according to Hijrī era) at 3 ghaṭis after sunrise.

DIVĀKARA (Birth śaka 1528)

He was the son of Nṛsiṃha, a scholar from the learned family of Golāgrāma (see page 154). He was born in Śaka year 1528. He received all his education from his uncle Śiva. At the age of 19 in Śaka 1547, he compiled a *jātaka* work named, *jātakamārgapadma*, which is also known as 'Padma-Jātaka'. In Śaka 1548, he wrote a commentary, named *Prauḍha-manoramā*, on Keśava's *Jātaka-paddhati*. He similarly compiled in Śaka 1549, a commentary on his own 'Jātaka' named 'Gaṇitatattva-Cintāmaṇī, with examples.

There is a commentary (with examples) known as Makaranda-vivaraṇa on Makaranda, a work intended to be helpful in Pancāṅga calculation.

His works show that he was proficient in grammar, logic, poetry and literature.

The author has seen the work, Makaranda Vivaraṇa. The remaining account has been given from the information contained in the *Gaṇakataraṅgiṇī*. His brother Kamalākara received his training from him.

THE SIDDHĀNTATATTVA VIVEKA OF KAMALĀKARA

Siddhānta tattva-viveka is a siddhānta work by Kamalākara. Kamalākara's family history has already been given in the account of Viṣṇu (Page 154). His birth date may be about Śaka 1530. The work Tattva-viveka was compiled at Vārāṇasi in Śaka 1580. It follows the modern *Sūrya Siddhānta* most faithfully. Kamalākara's pride in the Sūryasiddānta had reached such a stage that he felt

that whatever was not found in the *Sūryasiddhānta* was false, and even if the same method in the *Sūryasiddhānta* were crude, while that in another siddhānta more accurate, he would still regard the latter as faulty. Thus, for instance, the correction of *udayāntara* was discovered by Bhāskarācārya, but Kamalākara regarded it as erroneous since it was not given in the *Sūrya Siddhānta*. He likewise attempted to prove that the correct method of finding the length of the circumference of a circle was the one given in the *Sūrya Siddhānta*, *viz.* to multiply the square of the diameter by 10 and to extract the square root of the product, even though the method given by Bhāskarācārya is really more accurate. It is needless to say that he has adopted all things like the numbers of revolutions and other elements, from the Sūrya Siddhānta and has even borrowed some verses exactly word by word. This work contains 13 chapters on the following subjects :—mean places, true places, three problems, discs shadow, elevation of moon's cusps, rising and setting, possibility of eclipses, lunar eclipse, solar eclipse, conjunction of plantes with stars, Mahāpāta and problems. All these subjects comprise 3024 verses in different meters. They are intersperced with prose passages and he has added a chapter named "Śeṣa vāsanā" in which he has given the theory of those subjects in the body of the book which was not given at the proper place. This work has been recently published by Sudhākara Dvivedī at Vārānasī Series.

Although the great drawback of Kamalākara has been pointed out above, his works contain many new things not to be found in the earlier works. They are :—He has stated that the place of the pole star does not remain fixed owing to the precession of the equinoxes. Similarly, that the pole star which we see at present is not situated exactly at the pole (of the equator) and its place is found to have changed when observed early at night and late in the latter part of the night. He says that it is the view of the Greeks that the major part of the earth's surface is under water and only a minor part outside it. The distance, in degrees, of a place from any meridian, in the east-west direction, which is now known as longitude, was termed by him as *Tulāṃśa* and he has given a list of latitudes and longitudes of 20 cities as below on the assumption that Khāladātta, a city on the equator, was on the Prime Meridian :—

Place	*Latitude*		*Tulāṃśa*		*Place*	*Latitude*		*Tulāṃśa*	
	°	′	°	′		°	′	°	′
Kabul	34	40	104	0	Ahmedabad	23	0	108	20
Khambayat	22	20	109	20	Burhanpur	21	0	111	0
Ujjayini	22	1	112	0	Lahore	31	50	109	20
Indraprastha	28	13	114	18	Argalapur	26	35	115	0
Somanath	22	35	106	0	Vijapur	17	20	118	0
Varanasi	26	55	117	20	Golkonda	18	4	114	19
Lucknow	26	30	114	13	Ajmer	26	5	111	5
Devagiri	20	30	111	0	Multan	29	40	107	35
Kanauj	26	35	115	0	Mandava	27	0	121	0
Kashmir	35	0	108	0	Samarkand	39	40	99	0

He has described in detail, the method of taking observations by the quadrant "instrument" and has discussed different new subjects in the chapter on "three problems" and "eclipses". He has also mentioned that at the time of the solar eclipse, an observer on the moon's disc will be able to see the earth engulfed in the shadow. He remarks that the Greeks had observed the transit of Venus across the Sun's disc. The causes of the clouds, hailstorm, earthquake, and the falling of meteors, have been explained by him. They are not wholly true, they are at least not based on superstition and in the truth. His works show some new methods related to the study on arithmetic, geometry, mensuration and trigonometry. Other siddhāntas, assume 3438 units as the radius of the earth, and give values of the sines of angles at intervalsof $3\frac{3}{4}°$. He has assumed 60 units as the value for the radius of the earth and given values for the sines of each degree, which are very convenient. A table has been given for finding the right ascension of a planet from its longitude. Other Siddhāntas give neither this table nor the method ; these are given only in Keropant's work. In short, his work has many features. It is, however, very difficult to find out how many of them he can claim as his own. It is a matter of regret that original ideas appearing in his work were not further developed.

That his brother Divākara, was his guru, has already been mentioned above while citing the verses from his work. Kamalākara was bitterly opposed to Munīśvara, the author of the *Sārvabhauma-Siddhānta*. They were contemporaries. One wonders whether it was due to jealousy that he began to hate Munīśvara and consequently also Bhāskara's works. Ranganātha, Kamalākara's youngest brother, wrote *Bhangīvibhangī*, in order to refute Munīśvara's 'Bhangī', the method of finding the true places of planets. Munīśvara, in his turn, made a counter attack (*Gaṇakataranginī* page 92.)

RANGANĀTHA

He was born in the famous family of scholars at Golāgrāma (see genealogical table on page 154). His birth year may be about 1534. He wrote the '*Mitabhāṣiṇī*', a commentary on the Siddhānta śiromaṇi. Sudhākara writes that he had compiled an independent work, named Siddhānta Cūḍamaṇi. It has 12 chapters and contains 400 verses. It follows the *Sūryasiddhānta*. Ranganātha has mentioned the date of its compilation as follows :—

मासानां कूतिरब्धि ४ हृदयुतिरसौ खाब्जैर्विहीना तिथि
वर्णी ५ हृद्दह्नि २ हतोड्वासरमितिर्वारांग ६ भामात्पदं ॥
पक्ष: सर्वयुति: शको द्विखदिनै १५०२ र्युक्ता ।

Translation :—

Calculation based on the above data shows that this work was completed on Friday (6), the full moon (15) day of Pauṣa* (10), Śaka 1565**, the nakṣatra and the yoga on that day being Ārdrā (6) and Brahma (25) respectively.

* Sudhākara has arrived at Śaka 1562 as the date referred to in this verse ; but it is an error due to oversight. The third nakṣatra that he mentions was not possible on the fullmoon day of Pauṣa in that Śaka year. The nakṣatra happens to be the sixth ; and taking that into account, the sum would not come to 1562.

** The month seems to have been puzzled out by trial and error as the original verse does not contain any clue to its name or number. Pt. Sudhākara also remarks that number 10 has to be presumed here as the number of the month because it fits the case completely. (R. V. V)

SIDDHĀNTARĀJA

BY

NITYĀNANDA (Śaka 1561)

BRIEF ACCOUNT

Nityānanda compiled the work 'Sarva Siddhāntarāja' in the year Vikram Samvat 1696 i.e. Śaka 1561. He was a resident of *Indrapurī* near Kurukṣetra. His gotra was Mudgala, he belonged to the Gauḍa clan and was brought up in the Dulīnahaṭṭa tradition of teaching. According to Sudhākara, Dulīnahaṭṭa was his traditional native place. The names of his ancestors, from his father upwards, were Devadatta, Nārāyaṇa, Lakṣmaṇa and Icchā respectively.

Description of works. Their Special Features

The work 'Siddhāntarāja', is divided into two parts—Gaṇitādhyāya and Golādhyāya. The first part contains 9 chapters and deals with the following subjects : Mīmāṃsā (Rationale), mean places, true places, three problems, lunar eclipse, solar eclipse, elevation of moon's cusps, conjunction of planets with stars and shadow. The second part, Golādhyāya, contains chapters on the universe, the celestial sphere and instruments. The special feature of this work, which distinguishes it from all other Siddhānta works described so far, is that it follows the SĀYANA system. He has fully discussed in the first chapter on 'Mīmāṃsā' (Rationale) how the *Sāyana* system is the supreme system and how it is recognized as such by Gods and Ṛṣis. The numbers of revolutions and other elements of planets etc., are as follows :—

Kalpa 4,32,00,00,000 years.

The revolutions etc. in this period are :—

Sun	432,000,0000	Saturn	146835981
Sun's Apogee	171945	Sāvana days	1577847748101
Moon	57750968965	Solar months	51840000000
Moon's apogee	488327103	Intercalary months	1590968965
Mars	2296968639	Lunar months	53430968965
Mercury	17939534114	Lunar days	1602929068950
Jupiter	364356698	Suppressed tithis	25081320849
Venus	7022180538		

Number of divine years spent over creation from the beginning of Kalpa..........90410.

Number of solar days in a year 365.24253428

=365 days—14-33-7.40448

the tropical year =365 days—14-31-53.42 (By accurate modern methods).

It can be easily noted that there is considerable difference between the above figures and those given in any of the siddhāntas described before. The number of days in a Kalpa and the consequent length of the year deduced from it are less than those of others, and the numbers showing revolutions

are greater than theirs'. The number in the case of Venus is smaller, which apears to be due to some error.

The corrections to be applied to planets have been mentioned in the following verses :—

सृष्टयादितो गतसमा खयुगांगनागै ४ (?) ६४० स्तष्टा गतैष्यत इहाब्दचयोऽल्पको य:
ग्राह्य: स एव विबुधैर्ग्रहबीजसिध्यै ।।
बीजाब्दास्त्रयगसिषुभि : ४७३० क्षितिभुजै २१० रष्टाब्धिभि ४८० दोरसै : ६२०
पंचांगै ६५०..४९० रूपाभ्रचंद्रै: १०१० क्रमात् ।।
भुविश्वै १३१० दशसंगुणैश्च विहृता लब्धं कलाद्यं वियुक्
सूर्यादिग्द्युचरेषु युक्तमथ तच्चंद्रोच्चपाताख्यया ।।
सूर्योच्चे पंच लिप्ता: सदा स्वं ।।

The author remarks at the very beginning,—

दृष्टा रोमकसिद्धांतं सौरं च ब्रह्मगुप्तकं ।। पृथक् स्पष्टान् ग्रहान् ज्ञात्वा सिद्धांतं
निर्ममे स्फुटं ।। १४ ।।

" After studying the Romaka, Saura, and Brahma Siddhāntas, and after calculating places of planets, the writer compiled this accurate Siddhānta. "

It is not known which Romaka Siddhānta is meant here. The differences in the measures will show that it can neither be the *Romaka Siddhānta* of the *Pañcasiddhāntikā* group nor that of *Ptolemy*. The Samrāt-Siddhānta (Śaka 1561) also refers to Romaka Siddhānta. The author has no means at present to ascertain what Siddhānta it was or whether it was the same as the one seen by Nityānanda. The author of the work seems to have taken observations himself. There might have been Muslim astronomers at the Delhi Court in his time, and they might have had possessed some works on Muslim astronomy in their possession. A reference to some such works occurs in the Siddhāntsamrāt. Nityānanda might have seen those works also.

The author happened to see a copy of this work with the late Rao Saheb Viśwanāth Nārāyaṇ Manḍlīk. The copy had been made from a work belonging to a learned scholar at *Jaipur*. It appears that the siddhanta is well known in those parts. It is not known, however, if the work was ever made use of in the actual calculation of almanacs.

KṚṢṆA, Śaka 1575

There is a karaṇa work entitled Karaṇa Kaustubha, written in Śaka 1575. It was compiled by Kṛṣṇa, an astronomer of Kāśyapagotra and a son of one Mahādeo. It has not been mentioned what Siddhānta it follows. But the motions of planets and the epochal positions agree with those calculated from the Graha Kautuka and the Graha Lāghava, with slight modifications.

The author has made a salutation to KEŚAVA, the author of Graha Kautuka. He says in the beginning,

प्रकुरु तत्करणं ग्रहसिद्धये सुगमदृग्गणितैक्यविधायि यत्
इति नृपेंद्रशिवाभिधनोदितः प्रकुरुते कृतिकृष्णविधिज्ञराट् ॥

"Being ordered by King Śivājī to compile such a Karaṇa work as would enable astronomers to obtain figures agreeing with observarion, Kṛṣṇa, the King of astronomers has begun to compile this Karaṇa work."

This shows that he compiled the work with the help of the two works mentioned above and his own observations. Śiva, referred to by the author, is king ŚIVĀJĪ, the founder of the Marāṭhā kingdom. There is no doubt that, in Saka 1575 i.e. in 1653 A.D. the author of the work was engaged in making preparations for the writing of the work and for taking observations. Śivājī was 26 years old then, and was actually absorbed in the work of founding the kingdom. It is very significant that even in the midst of the turmoil, he instructed the author to compile a work which would give results agreeing with observation.

The following line of the author,

कृष्णः कोंकणसत्तटाकनगरे देशस्थवर्यो वसन् ॥

shows that he was a Deśastha Brāhmaṇa residing in the *Māwalā* territory near the Sahyādri ranges.

The mean places of planets are to be calculated from varṣagaṇa according to this karaṇa work. The ayanāṃśa is assumed to be zero in Śaka 450 and the annual motion 60″. Unlike the author of the *Grahalāghava*, this author has taken the help of sines and chords. This very writer compiled a very voluminuous work entitled *Tantraratna* and this work, he says, was only a part of it. The *Tantraratha* has not come to the author's notice.

PAÑCĀNGAKAUTUKA

BY

RATNAKAṆṬHA, (Śaka 1580)

This is a work cortaining tables, helpful in easily calculating necessary figures for the almanac. The epochal year in it is Śaka 1580. It has been compiled on the times of the Khaṇḍakhādya. The name of the author is *Ratna Kaṇṭha*. He was born in Śaka 1546. His father's name was Śankara. He compiled this work for his son, Śivakaṇṭha. The writer claims that the figures for the whole almanac can be compiled in two days only from this work. It has aready been observed (page 89) that he was probably a resident of *Kashmir*.

This work gives tables for calculating the ending moments of Tithis etc. from the positions of the Sun and Moon, and the values of the *bhogya* (unexpired) parts of tithis and other items. This work can be used for finding tithis etc., when the true places and motions of the sun and moon are first found ; it evidently entails greater labour than the work Tithi Cintāmaṇi.

VĀRṢIKA TANTRA

BY

VIDDAṆA

A work of this name was found at Sholapur for the first time. It has adopted the beginning of Kaliyuga as its epoch for calculation work, and that is why it is called a *tantra*. This *tantra* was compiled by VIDDAṆA,

the son of Mallaya of Kauṇḍiṇya gotra. No mention has been made of the date of the work or that of its author. There is a commentary on it written about Śaka 1634. (This Śaka has been taken for an example in it). The commen tator has not disclosed his name ; but his place of residence, according to the commentary, was *Baṅkāpur*. The *palabhā* of Baṅkāpur has been mentioned as 3-18 (hence the latitude would be about 15° 25′), and the longitude as about 13 yojanas (1°) west of Kārtika mountains. From this, the place appears to be situated in the *Dharwar* district. This fact and the writer's name would lead one to infer that this work had been in use in *Karṇātaka*, and the date of its compilation was earlier than Śaka 1600 ; it may have been even more ancient. It contains a verse from the *Grahalāghava*. It is not known whether the author of the *Grahalāghava* has taken it from this work or the author of this work has borrowed it from the *Grahalāghava*.

The length of the year and the revolutions of planets have beer taken from the modern *Sūrya Siddhānta*, and a correction has been mentioned for them. The correction for Mercury, as mentioned by Makaranda, is negative, while that given in this work is positive. Simiarly the Makaranda does not at all mention any correction for Mars, while this work gives plus $2\frac{2}{3}$ revolutions ; all other corrections are the same as those given in Makaranda.

From the list of corrections, this work does not appear to be older than Śaka 1400. The Aufrecht Catalogue mentions another work *Grahaṇa Mukura* by Viddaṇa.

PHATTEŚĀHA PRAKĀŚA

By

JAṬĀDHARA, Śaka 1626.

This is a Karaṇa work. The epochal year of this work is Śaka 1626 which was the 48th year of the reign of king Phatte Śāha of the Candra dynasty at Badri Kedar, near Śrinagar. Its author is JAṬĀDHARA by name. His father's name was Vanamāli, that of his grand father was Dūrgāmiśra and that of his great-grand-father, Uddhava. His gotra was Garga. Jaṭādhara was a resident of Sarhind*.

DĀDABHAṬA

The *Kiraṇāvali*, a commentary on the *Sūrya Siddhānta*, was written by DĀDĀBHAṬA or DĀDĀBHĀĪ, a Citpavan Brāhmaṇa, in Śaka 1641. His father's name was Mādhava and surname Gaoṅkar. A reference to this commentary has already been made in the course of the authors comments on the *Sūrya Siddhānta*.

ACCOUNT OF FAMILY

According to Aufrecht Catalogue Mādhava had written a work entitled *Sāmudrika Cintāmaṇi*. Nārāyaṇa, Dādābhaṭa's son, has written in the colophon of his Tājakasudhānidhi, that MĀDHAVA was " in the service of Śrī Īśa in the Pashupatinagar ", from which he appears to have been staying at

*Prof. Bhāṇḍārkar's *Report on the Search for Sanskrit Manuscripts*, 1883-84, p. 84

Vārānasī. Mādhava had two sons, of whom Dādābhaṭa was the elder. Dādābhaṭa had two sons, of whom NĀRĀYAṆA was the younger. Nārāyaṇa compiled the following works :—

(1) Horāsārasudhānidhi (2) Narajātakavyākhyā (3) A ' Praśna ' work entitled Gaṇakapriya (4) A 'Śakuna ' work, named Svarasāgara (5) Tājakasudhānidhi. The date of all these works appears to be about Śaka 1660.

JAYASIṂHA

Jayasiṃha was a unique personality so far as the science of Indian astronomy is concerned. Coperinicus was born in Europe about the same time as KEŚAVA Daivajñya and Gaṇeśa Daivajñya, the two research-minded astronomers, were flourishing in our country, and the condition of astronomy both here and abroad could be said to have been similar till that age. But a great transformation took place in the condition of astronomy in Europe from COPERNICUS onwards. One may safely say that the science has now attained the acme of knowledge so far as the motions and positions of planets are concerned. It is true that the discovery of telescope and the needs of navigation were particularly responsible for this remarkable progress; still, it must be admitted that unlike Europe, our country failed to produce a galaxy of talented and diligent scholars capable of bringing about a similar advance of knowledge. It is found, only JAYASIṂHA in our country could be named as the solitary exception, comparable with the European scholars of his time.

Jayasiṃha was a king in Rajputana. He ascended the throne at Ambher in Vikram Saṃvat 1750 (Śaka 1615, i.e. 1693 A.D.). Later on, he built the present city of Jaipur and made it his capital. In his work, Siddhārtasamrāt, he has been styled " Matsya deśādhipati ". He set himself the task of compiling a work, after taking observations wih newly built instruments, set up in newly built observatories, because no existing Hindu, Muslim, or European works could give results agreeing with observation ; and accordingly he accomplished his task with success . He established observatories at *Jaipur*, *Indraprastha* *(Delhi), *ujjayinī*, Vārānasī and Mathurā. He got built very big, immovable instruments, made of mortar and stone, huge in size and very useful for observation, because, he found that metallic instruments are very small in size and wear out easily. Of these, the Jaiprakāśa, Yantrasamrāt, Bhittiyantra, Vṛttaṣṣṭhāṃśa etc. were newly devised by him ; and after engaging a staff of competent astronomers as observers for seven or eight years, he compiled a work entitled *viz.* 'Muhammad ' in Arabic and Siddhānta Samrāt in Sanskrit, on the basis of the records of observations taken. At that time, MUHAMMAD ŚĀH was the Emperor of Delhi and the first work was named after him. It appears that it was also called ' Mijasti '. This work belongs to the year 1141 of Hijri era (i.e. Śaka 1650). He got the Siddhāntasamrāt compiled by a scholar, JAGANNĀTHA, about Śaka 1653 (i.e. 1731 A.D.). It is mainly a translation of the work, Mijasti. It consists of 13 chapters, contaning 141 articles and a study of 196 propositions (Kṣetras). The work records the observations taken in the year 1650-51-52 ; and the elements such as planteary motions have been determined, after comparing his own observations with those of ULUGH BEG and other ancient observers.

*The latitude of Indraprastha has been given as 28°39′ which tallies with the present day estimate.

The Siddhāntasamrāt could not be obtained in its complete form in this province. The Ānandāśrama possesses a copy of the book prepared from the incomplete work in the possession of the Rājajyotiṣi (palace Astrologer) of Kolhapur . It contains two chapters in the beginning which describe, by way of introduction, the earth and the celestial sphere. The first chapter contains 14 articles and a study of 16 propositions (Kṣetras), and the second, 13 articles with 25 theorems. The book contains, in addition, a study of instruments and problems in geometry and trigonometry, three problems and mean & true places. The " spaṣṭādhyāya " is incomplete, and this portion contains a study of 67 propositions. All these together make about 5500 verses. From this it appears that the complete work may have consisted of about 10000 verses. Sudhākara says that according to a legend, the number was about 50000; but it is an impossibility. Moreover, Sudhākara too has not seen the entire work.

If a description of the observatories built by Jayasiṃha, and of the observations taken, and the items of original information gleaned from these, be attempted, it would take a small volume. It is enough to state here, however, that *Jayasiṃha ensured a higher degree of accuracy* in the calculation of planetary positions and motions than that achieved in Europe in those days. This reflects great credit on him as well as this country. The length of the year adopted in this work is tropical and the rate of annual precession about 51″.4. The planetary places obtained from the work appear to be sāyana. We are instructed to take the nirayaṇa places obtained by applying the ayanāṃśa-correction. The numbers of revolutions and other elements also appear to have been given as in the Sūrya Siddhānta along with corrections to be applied to them.

It is not that the work in Arabic might have been entirely compiled by Jayasiṃha himself. He had many scholars under his patronage and he might have got it compiled by them. The Siddhānta Samrāt which is for the most part a translation of the Arabic work was compiled by Jagannātha. Nevertheless, Jayasiṃha was himself a good observer, a mathematician and an astronomer. The works mention the fact that some of the subjects were explained by him in quite a new way ; and the idea of first taking observations and then compiling a work that would give results in conformity with observations was first originated by him. He had engaged competent artisans and scholars knowing one or both the languages, Sanskrit and Arabic. He had sent astronomers even to foreign lands to take observations. It is obvious that the observation work has to be carried on at several places and by several persons working in co-operation.

The Siddhānta Samrāt describes the instruments newly designed by Jayasiṃha. A description of his observatories and instruments has been given later on in the chapter on 'Observations'.

The *Siddhānta Samrāt* refers not only to ancient works in Sanskrit but to a work compiled by ULUGH BEG, grandson of Tamerlane in the Hijrī year 841 (i.e. Śaka 1359). It refers also to a work compiled by *Boosanassar*, which seems to have been compiled 619 years before that of Jayasiṃha. This figure may be indicating years of Hijrī era. It refers to the *Romakasiddhānta* and to the Yavana (Arab) astronomers, *Batalmajuṣa* and *Awarakhas*–

Jagannātha translated in Śaka 1641, 15 books of Euclid's geometry in to Sanskrit, under orders of Jayasiṃha. It is called ' Rekhā-gaṇita'. It is well known in Jaipur province. There is a copy of this book in the Ānandāśrama library (Book No. 3693), Poona. It does not mention Euclid's name. It is said to have been prepared with the help of works compiled by Ṛṣis ; there is, however, no doubt that it was compiled with the help of Euclid's work. It may have been compiled from some Arabic work which did not make any mention of the original writer, or else which contained some words suggestive of the " apauruṣeya " (divine) nature of the work and a similar remark might have found its way into the Sanskrit work also.

Sudhākara writes that Jayasiṃha offered some villages to Jagannātha by way of reward and they are still in the possession of his descendants.

Jayasiṃha got another work entitled ' Kaṭar ', compiled by ' *Navanāsukhopādhyāya* '. It is an independant work different from Euclid though compiled on the same lines. It conains three chapters which respectively consist of 22, 23 (or 22) and 14, i.e. 58 or 59 theorems in all. The first two chapters deal with theorems about circles on spheres. This book was originaly written by ' *Sīvajñsayāsa* ' in the Greek language. It was then translated into Arabic under the orders of Abul Accās AHMED. There is a commentary on it compiled by NASIR. It has been stated in the work that it was translated from Arabic into Sanskrit.

The enterprises of Jayasiṃha were not continued further. No one makes any use of his observatories and now they are mostly in a dilapidated condition. Jayasiṃha's work, Siddhānta Samrāṭ also does not appear to have come into use ; nor have almanacs been rectified therefrom. The length of the year is still the same as before. And the same works which guided the almanac-makers before the time of Jayasiṃha continue to hold the field to this day. The fact that Jayasiṃha's works were not used even in Rajputana, is really very deplorable and thought-provoking.

VAIṢṆAVA KARAṆA

BY

ŚAṄKARA, Śaka 1688

Śaṅkara belonged to Vasiṣtha gotra and was a resident of the region around Raivatakā hill (near Dwarka). The names of his ancestors, from his father upwards were Śuka, Dhaneśvara, Rāma and Harihara. He compiled a Karaṇa work entitled *Vaiṣṇavakaraṇa* in Śaka 1688. Although he has observed in the beginning that he proposed to compile it according to Viṣṇugupta's views, he has, in reality, followed the Bhāskarācārya's views. He perhaps meant to name Brahmagupta, son of Jiṣṇu, in place of Viṣṇugupta. This work adopts a Zero ayanāṃśa for the Śaka year 445. The work contains about 300 verses. It is claimed that this Karaṇa work would give planets places agreeing with observation. But it contains nothing more than earlier works, Gaṇakataraṅgiṇī, pp. 110-111.

GRAHAGAṆITA CINTĀMAṆI

BY

MAṆIRĀMA, Śaka 1696

BRIEF ACCOUNT

Maṇirāma was a Yajurvedī Brāhmaṇa belonging to Bhāradwāja gotra. The names of his three ancestors, starting from his father, were Lālamaṇi, Devidāsa, and Līlādhara. His guru was one Vatsarāja of Kāśyapa gotra. All these names suggest that Maṇirāma was a Gujerāti. The verses describing his family history show that his name may have been simply RĀMA.

Outline of Work

The Grahagaṇita Cintāmaṇi has given epochal positions for the morning of Sunday, the first lunar day of Caitra Śukla, of Śaka 1696 (i.e. 13th March, 1774 A.D.). They are :—

	Sun	Moon	Moon's apogee	Moon's node
S.	11	11	1	
°	0	4	29	15
′	15	50	6	36
″	1	6	21	55

	Mars	Mercury's (mean) elongation	Jupiter	Venus's (mean) elongation	Saturn
S . . .	10	1	11	4	4
°	13	17	29	23	27
′	4	5	57	54	4
″	51	12	0	54	12

Difference from those of Grahalāghava (Gr. L.-23 cycles ; ahargaṇa=388)

	°	′	″		°	′	″
Sun	+0	0	24	Mercury's (Mean) elongation . .	+1	14	31
Moon . . .	+0	0	51	Jupiter	+0	20	33
Moon's apogee . .	+1	36	8	Venus's (Mean) elongation . .	−2	56	34
Moon's node . .	−0	17	22	Saturn	−0	9	17
Mars	−0	6	37				

This work has employed the same device as Grahaghava in order that ahargana may not exceed a certain number.In other words it has assumed a cycle of 11 years and the explement of the motion during this cycle is termed 'Dhruva'. These 'Dhruva' figures are more accurate than those of Grahalāghava. The author is a follower of the Sūrya Siddhānta ; still, he has not adopted the positions as they are actually obtainable from the Sūrya Siddhānta. Again, though the method of procedure adopted in the work is almost the same as that of Grahalāghava, the author has not relied upon that work too for the places of planets. From this and from his remark in the conclusion, viz. " I have compiled this work, after myself taking observations, according to the methods of observation described by learned men. Scholars may test their accuracy by means of instruments, " it appears that the writer has obtained the planets' places at the epoch, after actually taking obervations for himself.

He has mentioned a correction due to difference in longitude (rekhāntar) to mean places of planets. Similarly, he has mentioned the corrections of 'bhujāntar' and 'cara' for all planets'. The ayanāṃśas have been given according to the Sūrya Siddhānta. The method of calculating true places of planets is like that of Grahalāghava. However, the figures for the heliocentric and geocentric positions are somewhat different.

The work contains 12 chapters on the following subjects :—mean places, true places of the sun and the moon, true places of planets, calculation of the ascendant etc., lunar eclipse, solar eclipse, graphs, re-appearance of the moon, construction of the 'nalikā' instrument, elevation of moon's cusps, heliacal rising and setting and Mahāpāat. The number of verses in it are respectively 19, 11, 14, 7, 5, 3, 7, 3, 26, 4, 6, 15, i.e. 120 in all. There is a copy of this work in the Ānandāśrama (library), Poona. (Book No. 3103).

No Setback to Grahalāghava

A number of attempts appear to have been made to compile a work similar to the *Grahalāghava*. The author has not found among these any work as good as this one. Of course the author of this work cannot be credited with capacity for original work like that of the *Grahalāghava* ; still, it is only fair to observe that he has given planetary positions agreeing with observed results ; and, judged only as a karaṇa grantha, this work is by no means inferior to the Grahalāghava. Nevertheless, Grahalāghava has been in extensive use all over the country and in spite of its great antiquity it is not found inconvenient for calculation. Moreover, many astronomers have prepared tables in order to simplify all its calculation work. For all these reasons the Grahalāghava has not been beaten as yet by any of its successors.

BRAHMA SIDDHĀNTASĀRA, Śaka 1703

This is a work belonging to Brahmapakṣa. It contains 12 chapters. It has adopted Śaka 1703 as its epochal year. The first chapter comprising 124 verses, is a synopsis of the chapter on mean places from the Siddhānta Śiromaṇi. Then follows the main part of the original work. It follows the method of computing planets' places from ahargaṇa. Some of its methods are similar to those of the Grahalāghava. The author of the work, named BHULĀ, was the son of Nārāyaṇa and a devotee of goddess Devī ; he was a Brāhmaṇa belonging to Gārgya gotra, and used to reside at Dadhīci, a place st of the mouth of the Narmadā.

WORKS

All his works on astronomy have been compiled with a view to simplifying planetary calculations to be made according to the *Grahalāghava*. They consist mostly of tables, and are very useful for study, because solved examples have been given in them. The works are :—(1) *Graha Vijñāna Sāraṇī* : This contains tables useful for calculating mean and true places of planets. The Śaka years used in the examples are 1734, 39, and 44. (2) *Māsa-praveśa-sāraṇī* hows how to compute the true daily position of the sun, for the sake of finding the moments of the commencement of a new day, a new month, and a new year of life, according to Tājaka system. The solved example has adopted 1744 as the Śaka year, 4 as the palabhā, and 28 W. Yojanas as the longitude. (3) Lagna Sāraṇī : tables for finding ascendants. (4) Krāntisāraṇī : tables for finding the declination. Śaka year 1753 has been selected for the example. (5) *Candodayāṅkajāla* : Śaka year 1757 adopted in the example (6) *Drikkarma Sāraṇī* : Śaka year 1758 taken for the example. (7) *Grahaṇāṅkajāla* : The example has adopted Śaka 1755—1761 as the years (8) *A commentary* on the Pātasāraṇī (Tables for the calculation of Mahapāta) by Gaṇeśa Daivajña, Śaka 1444. The example adopts Śaka 1761 as the year. (9) *Yantra Cintāmaṇi-Ṭīkā* : This is a commentary on the work on instruments by Cakradhara.

Dinakara was an ingenious astronomer and his works show that he had a good knowledge of observations.

GRAHALĀGHAVA METHODS SIMPLIFIED

A number of astronomers possess tables like those prepared by Dinakara that are useful in making any calculation by the Grahalāghava methods and especially for finding the mean and true places of planets. The calculation which normally takes 2 to 2½ hours if done according to the method described in the Grahalāghava verses, can be finished in nearly half an hour with the aid of such tables. VĀMAN KṚṢṆA JOŚĪ, Kannaḍkar, published in Śaka 1803 a work, entitled, " Bṛhat-Pañcāng-Sādhanodāharaṇa " which contains such tables. The printed version of 'Keśavi (collected works of Keśava, the father of Gaṇeśa Daivajñya) contain similar tables. Nevertheless astronomers are found as do not have any idea of such devices and short cuts and are consequently required to follow the laborious method of calculation.

YAJÑEŚWARA ALIAS BĀBĀ JOŚĪ RODE.

BRIEF ACCOUNT

His gotra was Śāṇḍilya, his father's name was Sadāśiva and that of his grand father, Rāma. He was the grandson (daughter's son) of Cintāmaṇi Dīkṣit of Sātārā. When British rule was established in Mahārāṣṭra, a Sanskrit College was founded in Poona, and Yajñeśwara was a teacher* of astronomy there upto September 1838 (Śaka 1760). From what date he was there, is not known. The chief Paṇḍit and astronomer, Subājī Bāpū, of the Sanskrit School at Sihore,

*Mr. Chaplain, Commissioner of Southern Division, founded the Poona Sanskrit College in 1821 A.D. Afterwards the College underwent such a complete transformations in 1851 A.D. that it may as well be regarded to have ceased to exist. (See Report of the Board of Education, for 1840, 41, 51 & 52.)

in Malwa, had compiled a small work entitled Siddhānta Śiromaṇi Prakāśa in which he presented a comparative study of the mythological views about astronomy, those of the Sanskrit astronomical siddhānta works, and those of Copernicus. R.B. Godbole, author of the *Modern History of India* (Marāṭhī) writes that Yajñeśwara had compiled the work, "Jyotiḥ-Purāṇa- Virodha Mardan" in refutation of the work of Subājī Bāpu while Major Candy has observed that Yajñeśwara was very intelligent and learned, but a very bigoted champion of the mythological doctrine. But there is still another work 'Avirodhaprakāśa' by Nīlkāṇṭha, in which it has been shown that there is no contradiction between the teaching of the Purāṇas and those of the science of astronomy. Wilkinson, the Political Agent of Sihore, had a sound knowledge of Indian astronomy. He had got Siddhānta Śiromaṇi, printed at Calcutta in 1841 A.D. (Śaka 1763). It was on his advice that Subājī Bāpū compiled another work "Avirodhaprakāśa viveka" (Śaka 1759) in order to refute the arguments advanced in "Avirodhaprakāśa", and sent it to Bābā Jośi at Poona, and Bābā Jośi endorsed the views of the author, as can be seen from the relevant correspondence published in the original by the author of the *Gaṇakataraṅgiṇī**.

WORKS

The following are the works by Yajñeśwara :—His commentary, Yantrarāja Vāsanā, on the work, Yantrarāja, belongs to Śaka 1764. He has also written Anubhāvikā, a commentary on Golānand by Cintāmaṇi Dīkṣit. The commentary, Maṇikānti, on Laghu Cintāmaṇi, compiled by some Yajñeśwara may probably be the work of this very author. These works show that Yajñeśwara had a sound knowledge of Siddhānta works. He has referred to his work entitled, Praśnottarmālikā in his commentary on Golānand.

NṛSIṂHA, alias BĀPŪDEVA, Birth Śaka 1743

Brief Account

Bāpūdeva was one of those learned men who lived after the establishment of the British rule in India and who were proficient both in the Indian and Western systems of astronomy and mathematics. He was a Rīgvedī Citpāvan Brāhmaṇa, originally a resident of *Ṭonke*, on the bank of Godāvarī in Ahmednagar district. He was born on the 6th lunar day of the bright half of Kārtika in Śaka 1743 (i.e. 1st November, 1821). His father's name was Sītārām and mother's name Satyabhāmā. He received his elementary education in a Marāṭhī School at *Nagpur*, and in the same city he studied Bhāskara's Līlāvatī and Bījagaṇita, under the guidance of Ḍhunḍhirāja, a Kānyakubja Brāhmaṇa scholar. In Śaka 1760, L. Wilkinson, the Political Agent at Sihore, was impressed by Bāpūdeva's proficiency in Mathematics and took him to the Sanskrit College (Pāṭhśālā) at Sihore for further study. Here he studied Geometry and other branches of mathematics under the care of Sewā Rām. Afterwards, on Wilkinson's recommendation, he was appointed a teacher of Geometry in the Sanskrit College at Vārānasī in Śaka 1763 (i.e. 1841 A.D.) From that

*Śivalal Pāṭhak of Vārānasī had compiled a work entitled Siddhānta Manjuṣā, which was meant to refute the arguments of the Avirodhaprakāśa. Similarly, Bālakṛṣṇa, a disciple of Śivalal's younger brother had written a work "Duṣṭa-mukha-capetikā". Both these (works) had been compiled before Śaka 1759.

day he lived at Vārānasī till his death. He became the Head Teacher of mathematics in the same College. He retired from service in Śaka 1811. Afterwards, he died in the month of Vaiśākha in Śaka 1812, at the age of 69.

A number of students received their training under his supervision. He became an Honorary member of the Royal Asiatic Society of Great Britain and Ireland in 1864 A.D. and that of the Asiatic Society of Bengal in 1868 A.D. In 1869, he was made Fellow of the Calcutta University. He was also a Fellow of the Allahabad University. In 1878, he received the title of C.I.E., and in 1887 that of Mahāmahopādhyāya from the British Government on the occasion of the Golden Jubilee of the Queen Empress. The ruler of Jammu once awarded him a cash prize of Rs. 1,000 - for having correctly predicted a lunar eclipse.

The works compiled by him were :—(1) First chapter of Geometry (2) Part of a work on Trigonometry (3) The controversy about the Sāyana-system (4) A brief account of the teachings of ancient astronomers (5) Eighteen questions on strange subjects with their answers. (6) Tattvaviveka parīkṣā (7) A description of the instruments at Mān Mandir. (8) Arithmetic. All these works, both small and large are written in Sanskṛit and all of them have been printed. In addition to these he wrote (i) 20 verses to explain the theory of Calculus, (ii) some formulae of spherical trigonometry (iii) useful notes on the study of siddhānta works (iv) The Chedyaka, useful for Yantrarāja, and (v) the Laghu-Śaṅku-chinna-kṣetra-guṇa. These have not been printed. His Hindi works on Arithmetic, Algebra and Astrology have been printed. He examined the English translation of the Golādhyāya from Siddhāntaśiromaṇi by L. Wilkinson, and he himself translated the Sūrya Siddhānta. Both these works were prepared under the supervision of Arch-deacon Pratt and printed in 1861-62. He also published with critical notes the Gaṇita and Gola, parts of Bhāskara's Siddhānta Śiromaṇi, in Śaka 1788 and the work Līlāvati in Śaka 1805.*

Every year Śaka 1797 to 1812, he used to publish an almanac with the help of the *Nautical Almanac.* A description of the Almanac will appear hurther in the course of our study of Pañcāṅga. He did not, however, compile any work on the method of the computing the Pañcāṅga.

NILĀMBAR ŚARMĀ, Śaka 1745.

He was a Maithili Brāhmaṇa, residing at Pāṭalīputra (Patna), four miles from the confluence of the Ganges and the Gaṇḍakī. His father's name was Śambhu Nāth. He studied under the care of his elder brother, Jeevanāth, and later on for some days in the Vārānasī Sanskrit College. He was the Head astronomer at the court of Śiva, King of *Alwar.* He died at Vārānasī in Śaka 1805.

He compiled a work 'Gola Prakāśa' in Sanskrit in the western style. Bāpūdeva printed it at Vārānasī in Śaka 1793. It contains five chapters. The following subjects are dealt with in it :—The conception of sines, the theory of (plane) trigonometry and spherical geometry, and the theory of spherical

*This account is based mainly on the *Gaṇakataraṅgiṇī.*

trigonometry and problems. This work is very useful for those who do not understand English. He has written a commentary on some sections of Bhāskara's works. His elder brother Jeevanāth, wrote a commentary on Bhāskara's Bījagaṇita and astrological works like Bhāva Prakāśa.

VINĀYAK alias KERO LAKṢMAṆ CHHATRE, Birth Śāka 1746.

Brief Account.

Keropant Nānā was one of the renowned scholars who were proficient in Western learning and who flourished after the British rule became established in Mahārāṣṭra. He was particularly proficient in mathematics, astronomy and nature study. There is a coastal village, named Nāgāon, in Aṣṭāgar Prānt, about 26 miles to the south of Bombay. He was born there in May 1824. He was a Rīgvedī Citpāvan Brāhmaṇa, belonging to the Kāśyap gotra. He completed his studies of the English language and through that medium, the study of Western sciences at the Elphinstone Institute of Bombay. He was a pet student of Prof. Arlibar.

In the year 1840 A.D. an Observatory was built at Colaba, Bombay, to observe the celestial phenomena and to test the effects of magnetic attractions. When it was inaugurated by Prof. Arlibar, he appointed Keropant as an Assistant there. Later, on 7th June, 1851, the Poona Sanskrit College was converted into the Poona College ; and after some months, Keropant was appointed Assistant Professor to teach mathematics and natural Sciences to the Marāṭhī section and the Normal School. He used to teach these subjects, in the College through Marāṭhī as well as English. Later on, the Normal School section was separated from the College, and he worked as a teacher, and later on, he worked for some years more as Superintendent of the School. The Institution was also known in those days as Vernacular College. (It is at persent known as the Training College). In those days he used to lecture also in the Engineering College on the subject of Natural Science. Some time during this period he was the Head Master of the English School at Ahmednagar. In 1865, he was appointed a Professor of Mathematics and Natural Science at the Poona College, where he used to teach these subjects through English. The College, later on came to be known as the Deccan College. He retired from service in 1879 A.D. He was, at that time, drawing Rs. 1,000 per mensem and he received a pension of Rs. 5,000 per year, the maximum which a 'Native' could receive in those days. In 1877, he received from the British Government the title of 'Rao Bahadur' on the occasion of the Delhi Durbar. He died on 19th March, 1884, at the age of 60. He was popularly known as 'Nānā. His lifelong scholarly habits and his inmate goodness were the most notable and praiseworthy among his many fine qualities.

Works.

About Śaka 1772, Nānā compiled in Marāṭhī, a work entitled, *Grahasādhanācī Koṣṭake* (Planetary Tables) with the help of French and English works on astronomy, and published it in Śaka 1782, (1860 A.D.)*. There was no such work compiled before, either in Marāṭhī or Sanskrit, and hence it renks very high among works of similar nature.

*Kṛṣṇaśāstrī Godbole writes that it was compiled on the basis of a work published by R. S. Vince in 1808 A.D.

In this work, the length of the year is assumed to be the same as in the Sūrya Siddhānta ; and the positions and motions of planets have been adopted on sāyana basis. Hence, the planets' places calculated from this work are tropical or sāyana. The author has assumed Zeta Piscium to be the junction star of Revatī. It coincided with the vernal equinox in Śaka 496. We are asked to find the nirayaṇa places of planets, by assuming the ayanāṃśa to be zero in that year, and by applying the ayanāṃśa correction to the sāyana positions at the rate of 50″·1 per annum. The whole process amounts to the adoption of the correct length of the sidereal year, *viz.*, 365^{d}-15^{g}-23^{p}. Adopting this length of the year and 50″·2 as the annual rate of precession, Keropant Nānā began to publish since Śaka 1787 a separate almanac with the help of the Nautical Almanac. The late *Ābāsāheb Paṭwardhan* gave him very valuable help. It was due to his encouragement that the above work could be compiled and the almanac was published from year to year. The almanac was naturally entitled by Nānā as 'Pātwardhanī Pañcāṅga'. The positions of planets calculated from Nānā's work is fairly accurate ; but the work and the Patwardhanī Pañcāṅga are not now in use, and it may safely be said that no one follows the almanac. This almanac will be described in more details further on.

Nānā compiled a work on the calculation of tithis on the lines of the Tithi Cintāmaṇi. It has been printed in Vārānasī. No one could be found in this province to print it. It is almost unknown in this province, and this work as well as the *Grahasādhanācī Koṣṭake* are both out of print at present. The *Graha Sādhana* has not adopted the purely sidereal year and the places of planets are sāyana. Hence, the work, as it stands, is of no use in directly computing a Pañcāṅga belonging to any of the schools, *viz.* nirayaṇa according to the *Grahalāghava*, purely nirayaṇa or purely sāyana. Besides this it requires the use of logarithms and trigonometry ; and hence, the orthodox astronomers, are unable to make calculations from the work ; and it is doubtful if even half a dozen persons could be found among the newly educated people who could calculate from it.

Nānā wrote two books for Marāthī schools. They are :—(i) Physics and (ii) Arithmetic. Mahārāṣṭra can boast of thousands of people who could be called his disciples, direct or by tradition.

VISĀJĪ RAGHUNĀTHA LELE, Birth Śaka 1749.

Brief Account.

One of the most talented and ingenious astronomers that ever flourished in our country, Lele was born at *Nasik*, on Friday, the tenth lunar day of the dark half of Śrāvana, in Śaka 1749 (*i.e.* 1827 A.D.), the ascendant at birth being Capricorn. He was a citpāvan Brāhmaṇa of the Hiranyakeśī Branch of Kāśyap gotra. In his childhood he received some education in the Marāṭhī school at Nasik till he was 11, where be learnt arithmetic up to fractions, and he received some lessons in Sanskrit while residing with his maternal uncle. This was the only education imparted to him by teachers, but owring to his perseverance and intelligence he was able to solve mathematical problems that would baffle even University graduates in spite of their background of English education.*

*Lele was known to me personally and through correspondence. Most of this account has been written on the basis of this personal contact. A sketch of his life was published in the October 1888 issue of the monthly journal Balbodh.

Having passed some years in some trivial employment, he went to Gwalior about Śaka 1782. He was there employed in the Revenue Department and the Accounts Department of Scindia Govt. His Bālbodh and Moḍī handwriting was excellent. He was also very good at map drawing ; and not a single mistake was ever found to have crept into his accounts. Having put in 33 years service he retired about Śaka 1816 and he died at Gwalior in his 69th year, on Friday the 6th lunar day of the dark half of kārtika in Śaka 1817.

Sāyana Pañcāṅga

Many persons feel that the almanac should be sāyana. Many must have felt and did actually feel thus before Lele. The thought naturally crossed Lele's mind and he was convinced that the 'sāyanapañcāṅga, alone could be said to be in conformity with the tenets of religion. For some days, he used to compile a sāyanaalmanac for practical use with the help of the *Grahalāghava*, and later on with that of the *Nautical Almanac*. But he did not get any opportunity for publishing it for some years. He had acquired a working knowledge of English that enabled him to compute figures from the *Nautical Almanac*. Keropant began to publish an accurate nirayaṇa almanac from Śaka 1787 (*i.e.* 1865 A.D.). From that year Lele carried on a controversy with Keropant through the press under the nom-de-plume "Sphuṭavaktā Abhiyogī", (candid combatant) in order to convert Keropant to the Sāyana view. Keropant remained indifferent and Lele, finding that he (Keropant) did not appear to be impressed by the importance of publishing a sāyana pañcāṅga, which would conform to the tenets of religion, began to publish independently a sāyanaalmanac with the help of other co-workers from Śaka 1806. We shall have to revert to this almanac later on in the chapter on *Pañcāṅga*.

Lele did not compile any work from which to compute a sāyanapañcāṅga, and hence, the task of popularizing it is a matter depending upon outside factors.

CINTĀMAṆI RAGHUNĀTHA ĀCĀRYA

(Birth Śaka, 1750)

Brief Account.

He was for 17 years the First Assistant in the Astronomical Observatory at Madras. Cintāmaṇi Raghunātha Ācārya was an authority in the Madras Presidency just as Keropant was in this province and Bāpūdeva in the region around Vārānasī. He was born on the 6th day of the PAṄGUNI month of the Sarvajit Saṃvatsara in Śaka 1749, according to the solar reckoning, or on the 2nd lunar day of the bright half of Caitra of Śaka 1750, by the luni-solar reckoning *i.e.*, on 17th March, 1828. His mother tongue and the birth region appears to be Tamil (Dravid). He has himself written that he did not understand Sanskrit. Still he had a very sound knowledge of European astronomy and mathematics, and hence, that of Indian astronomy also. He actually used to take observations for a number of years. He was very well known in that respect. He was a Fellow of the Royal Astronomical Society in England since 1872. In 1847, he entered service in the Madras Observatory and he remained there till the end. He died on 5th of February (*i.e.* Pauṣa) in Śaka 1801, in his nd year. He belonged to a family of astronomers. His father

also had been an Assistant in the Madras Observatory. A catalogue of stars has been compiled by the Madras Observatory, for which observations of many of the stars were taken by Cintāmaṇi himself. He discovered two variable stars in 1867 and 1878. He was the first Hindu astronomer whose name is associated with a discovery of this nature.

Works etc.

He compiled a work entitled *Jyotiṣa Cintāmaṇi.* It consists of three parts. The first deals with mean motions, the size and magnitude of the earth and other planets etc. The second is devoted to their true places and motions and the third, entiled 'Karaṇa paddhati', contains tables for planetary calculations. This work appears to have been compiled in the Drāviḍian (*i.e.*, Tamil) language originally. A meeting was held in Madras in 1874 A.D. and the decision taken to arrange to publish its Sanskrit translation in the Tamil, Telugu and Devanagari scripts. It was estimated that the cost of the publication would be Rs. 7,000 for 500 copies, the whole work comprising about 800 pages of demi octavo size. The book however, was never printed.*

He used to publish an almanac, entitled *Dṛggaṇita Pañchāṅga* with the help of the *Nautical Almanac.* The author has seen an almanac for Śaka 1808, published after his death by his two sons. It seems to have adopted 22°5′ as the ayanāṃśa and the length of the year as given in the *Sūrya Siddhānta.* The elder son C. Rāghavācārya died about Śaka 1811. His younger son and brother-in-law, P. Rāghavācārya, the First Assistant in the Madras Observatory, jointly publish the almanac at present.

KṚṢṆA ŚĀSTRI GOḌBOLE, Birth Śaka 1753.

Brief Account.

He was a Citpāvan Brāhmaṇa, belonging to the Hiraṇyakeśi branch and of the Kauśik gotra. He was born on the 10th lunar day of the dark half of Śrāvana, Śaka 1753 (*i.e.*, on 1st September 1831) at Waī. He studied, in the beginning, in a Marāṭhī school at Poona and then at the Sanskrit Pāṭhśālā and the Poona College. He had a liking for mathematics from his very childhood. At the Sanskrit college he studied astronomy under the care of Śaṅkar Jośī. On the 19th of October, 1855, he was appointed a teacher in the Normal School of the Poona College. There he mainly taught mathematics. For some time during 1864-65, he had been appointed in the Colaba Observatory, Bombay. In 1865 he was again appointed in the Poona Training College. In 1866, he was transferred to the Hyderabad High School, Sind, and in 1867 to a High School at Karachi. In 1872, he worked as Asstt. Teacher in the Poona High School and later on for some days more in the Elphinstone High School, Bombay. Later on, in the same year, he was made the Head Master of the Anglo-Marāṭhī School, Phanaswāḍī, Bombay, and he remained there till March, 1882. Later on, he began to reside in his home at Poona, after

*In 1874, there was a transit of venus across the disc of the Sun. Raghunātha Ācārya had got its calculation published in several languages. His pamphlet in English contains an account of this laborious task. The auther has given the accont of Raghunātha Ācārya, mainly on the basis of this pamphlet and also from the information published n newspapers and sent to him by the well-known Nateś Śāstrī of Madras.

his retirement from Service. He died on 22nd November, 1886. While he was in Sind, he studied the Sindhi language thoroughly and learnt even Persian. He used to be an examiner for the Sindhi language, in the Bombay University, from 1871 to 1879.

Works.

He and Wāman Kṛṣṇa Jośi Gadre, jointly translated the *Grahalāghava*, with examples, into Marāṭhī and published it in Śaka 1778. It is almost a translation of the Viśwanāthī commentary. A second edition of this work is now published. Kṛṣṇa Śāstrī has also written a book on the theory underlying the *Grahalāghava* in Marāṭhī and it is learnt that he has corrected in it the errors in the Mallārī commentary. It is worth publishing. In addition to this, a short article of his, on the history of astronomy, written about Śaka 1807, has come to the author's notice. The *Jyotiṣśāstra*, a Marāṭhī book written on the basis of Chambers's book in English, was printed and published in 1862 A.D., but it is not now in use. A Marāṭhī translation of *Hudson's* Algebra, had already existed ; he published it in 1854, after correcting it. It was in use in the Education Department for several years. In 1874 A.D., he and Govind Viṭhal Karkare translated in to Marāṭhī four parts of Euclid's geometry. Before this date, a Marāṭhī translation of Euclid's geometry by Nānāśāstrī Apṭe was in use in schools. Later on, from 1885 A.D. the book, by late R.M. Devakule, came into use. In 1882 A.D. Kṛṣṇa Śāstrī published an article entitled "Antiquity of the Vedas" in the Theosophical magazine and also got it printed separately. The author does not think that it contains any evidence on the strength of which it could be proved beyond doubt that the Vedic period was more ancient than 1200 B.S. (before Śaka). He attempted to prove that the antiquity of the Vedas extends beyond 30000 B.S., by interpreting the line "māsānāṃ Mārgaśīrṣohaṃ" from the Gita, as indicating that "the equinox used to occur in Mārgaśīrṣa". He published a book on Arithmetic in Sindhi in 1869 and a good book on Marāṭhī Grammar also in Sindhi in 1867 A.D. Its popularity is proved from the fact that it went through its third edition in 1895*. He also published in 1868 A.D. a book on the Sindhi language.

He had once published his view that the calculation for the five parts of the *Pañcāṅga* should be made on the basis of the mean places of the Sun and the Moon.

Wāman Kṛṣṇa Gadre, referred to above, published in Śaka 1791, a work entitled *Pañcāṅga-sādhanā-sār*. It contains a Marāṭhī translation of the *Laghu Cintāmaṇi*, along with examples. The tables, however, contain a good many errors.

Living Authors of Astronomical Works,

1. *Venkaṭeś Bāpūjī Ketkar* :—
(Birth date :—Friday, the 14th lunar day of the bright half of Pauṣa, Śaka 1775).

*This has been printed by Ananta Kṛṣṇa, the son of the Śāstrī, who has given in it, the biography of Kṛṣṇaśāstrī. The above account has been given on the basis of the biography as well as the information collected by the author.

He is a Rigvedī Citpāvan Brāhmaṇa belonging to Gārgya gotra. He is working as a teacher in the Education Department in this province since 1874 A.D. He has been the Head Master of the English Hign School, at *Bagal-Kot*, for the last several years. He received most of his education at Belgaon. His father also was a good astronomer. He had rendered into Sanskrit Keropant's Planetary Tables, but it was not printed. For the last five or six generations the family had been living at Paiṭhaṇ. But Bāpū left the place for Nargundās and later on shifted to Rāmdurgās. He had the patronage of the Chief of that State.

Venkaṭeś compiled a very useful work in Sanskrit, entitled "Jyotirgaṇita" about Śaka 1812. He has adopted in it, Śaka 1800 as the epochal year. This has been compiled on the basis of those French works which are being used in compiling the *Nautical Almanac*. The planets' places, calculated with the help of this work, are very accurate, in fact they are correct within 1′ as compared with those of the *Nautical Almanac*. Never before has such a work been compiled in this province, not even in our country. This work has adopted for the length of the year the correct value of the sidereal year *viz.* 365d-15-22-53 and 50″·2 (the actual value) as the annual rate of precession. Assuming Zeeta Piscium to be the junction star of Revatī, he has given its sā yana longitude, or in other words, the ayanāṃśa for the Śaka year 1800 as 18° 10′ 25″. The author had suggested to him to adopt for the ayanāṃśa a figure approximately equal to that of the *Grahalāghava*. A star whose longitude would be equal to it could have been adopted as the initial point. But even Ketkar has come to realise the fact that the ayanāṃśas can be nearly equal to those of Grahalāghava, by assuming 180° as the longitude of the star Citrā (Spica). In short, if he had assumed 22′ as the aproximate ayanāṃśa for Śaka 1800, the author feels that Ketkar's work would have easily come into general use. The work mainly consists of four parts. The first contains the calculation of the almanac. The epochal positions are all given for the moment of the true Aries Ingress. The second part treats of the calculation of the places of planets. It includes the mean and true longitudes of planets, the right ascension, longitudes of star etc., heliacal rising and setting of celestial bodies, and other subjects. The third contains the calculation of phenomena like eclipses, conjunctions, elevtaion of moon's cusps. The fourth contains the calculation of the ascendant etc. required in the case of three problems. The treatment of each subject has, everywhere in the book, adhered to the following order :—Method, example, tables and then the theory. The work contains tables for almost all calculations, and the calculators who do not understand the use of trigonometry and longarithms can easily make calculations from the book. Keropant's almanac can be compiled with the help of this Book. This book has not been printed as yet.

(2) Bāl Gangādhar Ṭilak

(Date of birth :—Wednesday, the 6th lunar day of the dark half of Āṣāḍha of Śaka 1778, the ascending sign being Cancer.). He is familiar not only in this country but even in foreign lands. He was for many years the Chief Professor of mathematics and astronomy in the Fargusan College.

He wrote a book in English entitled *ORION*, in 1893 A.D. (Śaka 1815) in which he has discussed in an accurate and elaborate manner the question of date of the Vedas and shown that some of the Vedic hymns were compiled when the vernal equinox was situated in the Orion group of stars, that is, about 4000 years B.S.

(3) *Vināyak Pāndurang Khānāpurkar* :—(Birth in Śaka 1780).

He was a Rigvedi Deśastha Brāhmaṇa, belonging to Jamadagnya gotra and a resident of Khānāpur, in Sātārā district. He has studied Sanskrit, astronomy and other subjects in the orthodox manner and also European mathematics and astronomy under the guidance of Keropant Nānā Chatre and Rāoji Moreśwar Devakule. An Association known as the Veda-Śāstrottejak-sabhā was started in *Poona* from Śaka 1796 and he was examined by the Association in the subjects of Indian Astronomy and Sanskrit Grammar.

He has compiled a *tājak* work, entitled *Vaināyakeeya Dwādaśādhyāyī*, by which the annual reading of a horoscope can be given with ease. He has similarly written the following books in Sanskrit :—The *Kundasār* ; the *Ardhakāṇḍa*, a versified Sanskrit translation, of the general enunciations of all theorems in the two parts of Euclid's Geometry, and the Siddhāntasār. In the last named work, he has explained the question of the movement of earth etc. according to the modern European view. He has translated into Marāṭhī, Bhāskara's Līlāvatī, Bīja and Golādhyāya, adding an explanation of the theory and he is at present translating the Gaṇitādhyāya. These works are not yet printed.

(4) *Sudhākara Dwivedī* :—(Date of birth :—Monday, the 4th lunar day of the bright half of Caitra, Śaka 1782).

He is at present the Head Teacher of mathematics and astronomy at the Sanskrit College, Vārānasī. He was appointed in the place of Paṇḍit Bāpūdeva, after his retirement in Śaka 1811. He was formerly the Chairman of the Library Committee in the same College. The title of Mahāmahopādhyāya has been conferred on him by the British Government.

The following are the Sanskrit works compiled by him:—(1) The *Dirghavṛttalakṣaṇa* (śaka 1800). The author described in details the properties of the ellipse, along with its theory; (2) the *Vicitra Praśna* (Interesting problems), Sabhang, in Śaka 1801. This contains 20 difficult problems in mathematics, along with their solutions; (3) the *Vāstava Candra Śṛngonnati-sādhana*. After pointing out the defects in the calculation of the elevation of the moon's cusps by the methods advocated by Lalla, Bhāskara, Jñyānarāja, Gaṇeśa, Kamalākara and Bāpūdeva, he has given in this, the correct method of calculating it accurately with the modern methods of European astronomy. This contains 92 verses; (4) the *Dyucara Cāra* (Śaka 1804). This contains a discussion of the orbital paths of planets according to modern European astronomy; (5) *Piṇḍa-Prabhākar* (Śaka 1807). This is a work devoted to the subject of house building; (6) the *Bhābhramarekhānirūpaṇa*. This is devoted to the consideration of the subject of "Sūcī-Chedana" corresponding to a given shadow; (7) the *Dharābhrama*: It considers the diurnal rotation of the earth; (8) the *Grahaṇa Karaṇa*. This describes the method of calculating an eclipse; (9) the *Golīya*

Rekhāgaṇita i.e. Spherical Geometry; (10) A Sanskrit translation of the 6th, 11th and 12th books of Euclid, in verse form, and (11) the *Gaṇaka Taraṅgiṇī* (Śaka 1812). It contains a history of Indian astronomers. It was, in the beginning, published in *Paṇḍit*, a monthly journal of Vārānasī. It was published separately in book form later on in Śaka 1814 and containts 124 pages of octavo size. Most of the remaining works have been printed. The following are the commentaries edited or written by Sudhākara :—He edited the *Yantrarāja* in Śaka 1804, along with the commentary, *Pratibhā Bodhak*, dated Śaka 1795, as also the commentary by Malayendusūrī. He published Bhāskara's *Līlāvatī*, with a new theory and certain special features in Śaka 1800. He also published Bhāskara's "Bīja" with a new commentary. He wrote a commentary, "Vāsanā Vibhūṣaṇa" on Karaṇa Kutūhala, which was printed in Śaka 1803. He wrote in Śaka 1810, a commentary named "Pañcasiddhāntikā Prakāśa" on Varāha's *Pañcasiddhāntikā*. The work containing the commentary, along with an English translation of the original by Dr. G. Thibaut, the then Principal of Vārānası Sanskrit College, was published in 1889 A. D. All these commentaries are written in Sanskrit. In addition to these, he edited and published the 'Chādak Nirṇaya' by Kṛṣṇa, "Siddhāntatattva-viveka" by Kamalākara and "Dhīvṛddhida tantra" by Lalla, in the Śaka years, 1806, 1807 and 1808, respectively. He is at present engaged in getting the revised edition of the Bṛhat Saṃhitā with Utpal Tīkā through the press. He has compiled a work, "Bhāṣā bodhaka", in Sanskrit, about (the teaching of) a language. He has written two books in Hindi, on Mathematics, entitled *Calan Kalan* i.e. Calculus, and has also compiled a Hindi Grammar.

The *Gaṇaka Taraṅgiṇī* by Dwivedī is on the whole a useful work. From this and from all his other works his profound knowledge of Indian and European mathematics and astronomy becomes evident. Still, he has, at places, passed some baseless and fantastic remarks in the *Gaṇaka Taraṅgiṇī* such as the following :—"Āryabhaṭa introduced the system of denoting numbers, by a new code with a view to keeping secret the numbers of revolutions and other elements which he secured through the favour of some Greek scholar whom he revered as a deity', or 'Bhāskarācārya has described the origin of *jya* at the end of his work, without explaining the underlying theory. It can be surmised from this that he learnt from some Greek traveller only the method and not its theory'. He has the ability to compile a work in Sanskrit on the lines of the French works, which are being used in compiling the English *Nautical Alamanac*. It is desirable that he should compile one himself.

FURTHER INFORMATION ABOUT AUTHORS AND WORKS BELONGING TO PERIODS PRIOR TO ŚAKA 950

After about 250 pages of the present work were printed, the author came-across two or three books not seen before, which contains information about some astronomical works and he proposes to give here extra information collected from them. Mahomed of Ghazni had brought to India a Muslim scholar, named, *ABU AL REHAN MOHOMED BIN AHMED AL BERUṆĪ*. He was born at Khiva in 973 A. D. He became a Minister to the King of that State. Later on, the province was conquered by *MAHMUD* and *BERUṆI* was brought to India, as a man under surveillance. Beruṇī lived in India from 1017 to 1031 A. D. He wrote a work in Arabic, entitled INDICA, about the year 1031-32 A. D. (i.e. Śaka 953). It contains a description of several sciences

then known in India. Beruṇī had learnt Sanskrit and had studied several works written in Sanskrit. He had paid special attention to astronomy and translated some astronomical works into Arabic. Edward C. Sachau, a Berlin Professor has translated his work, "Indica" into English. It has been published in two volumes. The author gives the information gathered mainly from this work about authors who lived before Śaka 950.

SPREAD OF HINDU ASTRONOMY AMONG MUSLIMS

The Sind province was under the control of the Caliphs of Bāghdād for someyears. During the reign of Caliph *MANSOOR* (753 to 774 A. D.) some ambassadors were sent to his court by the ruler of a State in Sind in 771 A. D. They were accompanied by some astronomers. It was at the hands of these astronomers that some astronomical works in Sanskrit were translated into Arabic. A Hindu astronomer was staying at Bāghdād in 778 A. D. During the reign of Caliph Haroun (786-806 A. D.) also some Hindu works on medicine and astronomy were translated in Arabic. It appears that in those days Brahmagupta's Brahma Siddhānta and Khaṇḍakhādya had already been translated and independent works were compiled in Arabic with the help of different Sanskrit astronomical works.

The Arab astronomers *AL FAZARI*, *YAKUB-BIN-TĀRIQUE*, and *ABU AL HĀSĀN*, lived in the latter half of the 8th century A. D. They compiled astronomical works in Arabic with the help of the Indian astronomers referred to above. These works are not at present available; still Beruṇī had with him the works written by these three astronomers. He has often referred to the works written by the first two. Those works contained several of the following subjects usually found in Sanskrit works, viz. measures of time, numbers of the revolutions of planets in Mahāyuga or Kalpa ; lengths (in yojanas of planetary orbits, calculation of ahargaṇa for finding the mean positions) of planets ; sines of angles ; rising and setting of planets ; first visibility of the moon, etc. The Arabs first learnt astronomy from the Hindus and then they came to know of Ptolemy's work. Al Fazari was the first to teach Hindu astronomy to Mahomedans. The Khaṇḍakhādya had already been translated into Arabic when Yakub compiled his work. That translation may have been made by Al Fazari.

THE PULIŚA SIDDHĀNTA.—

Beruṇī had this Siddhānta with him together with a commentary on it. He was translating it into Arabic. He has given the number of revolutions of planets and those sāvana days in a Mahāyuga, etc., as mentioned by Puliśa, and they agree entirely with those cited by Utpala as belonging to Puliśa Siddhānta. These numbers have been mentioned before (page 18). They do not contain the numbers of the revolutions of Rāhu and moon's apogee which have been given by Beruṇī as 488219 and 232226 respectively. The longitude of the sun's apogee has been stated to be 80°. Beruṇī states that the Puliśa siddhānta describes the yuga system according to the Smṛtis, but it gives 1008 as the number of Mahāyugas in a Kalpa and 14 Manus consisting of 72 Mahāyugas each. The 'twilights' (Sandhyās) and 'semi-twilights' (San-

dhyāṅśas) are, of course, absent, and the Yuga is supposed to begin at midnight. He says "I think that Puliśa siddhānta is the name given after Paulis, the Greek resident of the city of Saintra, and that Saintra is the same as Alexandriā." But he also observes that the Greeks had no yuga system among them. It clearly shows that Utpala's Puliśa siddhānta was widely used at the time of Beruṇī.

*ĀRYABHAṬA I** :—Beruṇī cites the numbers of revolutions of planets given in Abu-al-Hāsān's work and most of these tally with the numbers given by Āryabhaṭa I ; and those that do not differ probably through the errors of copying. Beruṇi had with him some part of the work Āryabhaṭīya and its Arabic translation. This translation must have been made during the reign of Caliph Mansur.

VARĀHA MIHIRA :—Beruṇī has given Śaka 427 as his date. Beruṇī had translated his works Bṛhatsaṃhitā and Laghujātaka into Arabic. The commentary on the *Bṛhajjātaka* by Balabhadra has been referred to by Beruṇī. Sudhākara writes that Varāha's works *Yoga Yatra*' and *Vivāhapaṭal* are available at Vārāṇasī. According to Utpala, there was a work entitled "Samāsa Saṃhitā" by Varāha. It may have been an abridged version of Bṛhatsaṃhitā.

BRAHMAGUPTA :—On the basis of Beruṇī's works, Prof. Sachau observes, "Brahmagupta occupies an important place in the history of oriental culture. Brahmagupta taught astronomy to the Arabs before they came to know of Ptolemy's works, since, references to the works 'Sindhind' and 'Al-Arkand' frequently occur in Arabic literature ; these are the translations of Brahmagupta's works, Brahma Siddhānta and Khaṇḍakhādya". The translations may have been made during the reign of Caliph. Mansur, and it appears from this, that Brahmagupta's works had a wide spread influence in the Sind Province. Beruṇı has repeatedly referred to Balabhadra's commentary on Khaṇḍakhādya. Beruṇī had translated Brahma Siddhānta and Khaṇḍakhādya into Arabic. He observes that the Arabic translations made before his time were not correct. These translations have not been available so far. Beruṇī had lived mainly in Sind for a good many years. His remarks, at several places, show that Brahmagupta's works had a great influence in that province in those times.

LALLA:—The author of the *Gaṇaka Taraṅgiṇī* also gives Śaka 421 as his date. But it has aready been proved (page 94) that it is wrong. Bhāskarācārya has, in the Golādhyāya, quoted Lalla's verse on the calculation of

---

* (Beruṇī has referred to the Āryabhaṭa of Kusumpūr and to another Āryabhaṭa who lived earlier. The author could not obtain the work of the older one, but Beruṇī remarks that the Āryabhaṭa of Kusumpūr was his follower. Both of them have been referred to by Beruṇi at 30 places. After reading all those passages, it is found that the description completely applies to the first of the two Aryabhaṭas formerly described (page 51 and 95) The number of revolutions of planets and such other matters referred to by Beruṇī as to differentiate one from the other very clearly, do not apply to the second Āryabhaṭa, and he was not the follower of the first. From this it follows that the two Āryabhaṭas referred to by Beruṇī are in fact, one and the same person. Even Prof. Sachau, did not note this fact pointed out here. The second Āryabhaṭa who figures in the auhors account, may have lived before Beruṇī, and although it is evident that his work was not seen by Beruṇī, it appears that he laboured under a misunderstanding due to hearsay reports about the existence of two Āryabhaṭa. This leads to the inference that Āryabhaṭa II, may have lived only a century or a half before Śaka 950, and confirms the author's former estimate of his date.,

the area of the surface of a sphere and refuted the method suggested in it. This shows that Lalla may have written a work on arithmetic. Sudhākara says that he may have a work to his credit even on algebra. Berunī's works contain something or other by way of description of famous astronomers who tlived before Śaka 950; but they do not mention Lalla's name even once. It shows that at least till Śaka 950, Lalla's works were not well known in Sind, Punjab, Kashmir, even the major part of Northern India. From this and from the fact that the first Ārya Siddhānta, as modified by the application of Lalla's cor rections, was in use in the Deccan, he appears to have been a resident of the Deccan.

ŚRĪDHARA :—His work on arithmetic, known as "Triśatikā" *consisting of 300 couplets, is in the Government Library, Vārānasī and it has been remarked in the very beginning of the work :

नत्वा शिवं स्वविरचितपाटया गणितस्य सारमुद्धृत्य । लोकव्यवहाराय प्रवक्ष्यति श्रीधराचार्यः ॥

"Śrīdharācārya, after saluting God Śiva, compiles for the benefit of the public, this work which contains the gist of his (earlier) work on 'Pāṭīgaṇita'.

This means that Śrīdharācārya must have compiled a second work on Arithmetic which was larger than the *Triśatikā*. The *Triśatikā* used many unusual terms like *stambhoddeśa* for *iṣṭakarma* (unitary method), *pratyutpanna*** for *guṇākār* (multiplication) etc. which are different from those used in Līlāvatī. It includes chapters on both arithmetic and mensuration. There is a work named *Nyāyakandali* on logic, and its author's name also is Śrīdhara. The work was written in Śaka 913. Authors of works other than astronomical do not generally mention their dates. It appears from this, says Sudhākara, that the author of Triśatikā and Nyāyakandalī is the same one person. Baldeva was the name of the author of Nyāyakandalī and his mother, Abvokā. The village of Bhūrisṛṣṭi in the territory of Dakṣiṇarāḍhā was his place of residence.

Bhaṭṭa Śrīdhara compiled the work Nyāyakandalī on the request of Pāṇḍudās. This account, however, is not given in the *Triśatikā* ; and the date of Śrīdhara, the author of Pāṭīgaṇita, as established from the date of Mahāvīra above (page 95) is more reliable than that inferred simply on the basis of the similarity of names. Mahāvīra has quoted Śrīdhara as follows :—

ऋणं धनर्णयोर्वर्गौ मूले स्वर्णे तयोः क्रमात् ॥

It is true that as the line is in 'anuṣṭup' metre it could not have occurred in Trīśati which is compiled in Ārya metre ; still it may have been borrowed from Śrīdhara's larger work on Pāṭīgaṇita or from his algebra. The Aufrecht Catalogue mentions "Triśatigaṇitasāra" as a work by Śrīdhara. It appears from this that Śrīdhara's work *Gaṇitasāra*, procured by Colebrooke and the *Triśati* mentioned by Sudhākara are one and the same work. There is another work, Jātakapaddhati attributed to Śrīdhara which may have been compiled by Śrīdhara, the author of the *Pāṭīgaṇita*.

* This has been stated chiefly on the basis of the *Gaṇaka Taraṅgiṇī*.

** The term *pratyutpanna* is found in Brahmagupta's works.

BṚHANMĀNASA KARAṆA:—According to Beruṇī, the auhor of this work is Manu, and the work has a commentary by Utpala and it was reproduced in an abridged form under the name of *Laghumānasa* by Munjāl. As the *Laghumānasa* belongs to Śaka 854, Bṛhanmānasa may have been compiled about Śaka 800.

BALABHADRA:—Beruṇī has given several quotations from his works or his commentaries. According to Beruṇī, he had compiled works on each of the sections "Gaṇita, Saṃhitā and Jātaka", and had written commentaries on the *Khaṇḍa Khādya* and the *Bṛhajjātaka*. The work on "gaṇita" has been called a 'tantra' by Beruṇī, which indicates that it advocated the calculation of ahargaṇa from the commencement of Yuga. The quotations given by Beruṇī show that there was also a commentary by Balabhadra on Brahmagupta's Siddhānta. Beruṇī has given quotations from the commentary on the "yoga-śāstra' of Patanjali, and Prof. Sachau infers that the passages were written by Balabhadra as is indicated by the context; and as the major part of the passages is devoted to questions of astronomy, the inference seems to be correct. Balabhadra's works mentioned the latitudes of *Kanauj* and *Sthāneśwar*, which indicates that he may have been a resident of that area. His date appears to be about Śaka 800.

KARAṆASĀRA BY VITTEŚWARA (Śaka 821)

Vitteśwara, son of Bhadatta (or Midhatta) had compiled a work called Karaṇasāra. It has adopted Śaka 821 as the epochal year. According to Beruṇī, Vitteśwara was the resident of Nāgpur. His work mentions 34°-9' as the latitude of Kashmir ; and it refers to the motion of the Saptarṣīs (the Greater Bear), on which the popular system of reckoning time, currentin Kashmir, is based, and from this I feel that he may have been a resident of Kashmir. The Karaṇasāra described the method of calculating the mean longitudes of planets from the epochal planetary positions given for the moment of the mean Aries Ingress. Beruṇī has given the method (mentioned in the work) of finding the tithi at the moment of mean Aries Ingress (tithi-śuddhi) in terms of degrees, which can be explained if the number of revolutions of the Moon in a Mahāyuga be assumed to be 57753336. This number is given in the Sūrya, Siddhānta the Puliśasiddhānta cited by Utpala, and the First Ārya Siddhānta Beruṇī had with him the Arabic translation of the work made by some one else before his time. The Aufrecht Catalogue does not mention this work at all. From this it seems that it is not available anywhere now. There lived one Vateśwara who was the author of some astronomical works ; and this Vitteśwara mentioned by Beruṇī may have been the same as Vateśwara.

LAGHUMĀNASA BY MUNJĀL (ŚAKA 854):—Munjāl was a resident of the Deccan. He compiled Laghumānasa which was an abridged version of Bṛhanmānasa. Beruṇī observes that it has adopted 6°-50' as the ayanāṃśa in Śaka 854 and 1' as the annual rate of precession. From this, according to Munjāl's view, the zero precession year comes to Śaka 444 elapsed. Beruṇī has stated the name of the author to be something like 'Punjāl'. The author of the *Gaṇakataraṅgiṇī* writes, "I have seen Laghumānasa, a short work of 60 verses in 'anuṣṭup' metre. It belongs to Śaka 854. The work does not men tion Munjāl's name explicitly, but contains at the end the line 'thus ends (the

work) compiled by Munjāl Bhaṭṭa'. Colebrooke has recorded the dates* of some astronomers as furnished by the astronomers at Ujjayinī, according to which the date of Munjāl is Śaka 854. Bhāskarācārya has given the equinoctial motion as mentioned by Munjāl. This shows that the author of Laghumānasa referred to by Beruṇī, is Munjāl himself. Munīśwara has given, in his commentary called Marīci, the following quotation from Munjāl :—

उत्तरतो याम्यादेशं याम्यांतात्तदनु सौम्यदिग्भागं ।
परिसरतां गगनसदां चलनं किंचिद्भवेदपमे ।।
विषुवदपक्रममंडलसंपाते प्राचि मेषादिः ।
पश्चात्तुलादिरनयोरपक्रमासंभवः प्रोक्तः ।।
राशित्रयांतरेस्मात्कर्कादिरनुक्रमान्मृगादिश्च ।
तत्र च परमा क्रांतिर्जिनभागमितात्र तत्रैव ।।
निर्दिष्टोऽयनसंधिश्चलनं तत्रैव संभवति ।
तद्भगणाः कल्पे स्युर्गोरसरसगोंकचंद्र १९९६६९ मिताः ।।

"While the celestial bodies move in the sky from north to south and again from the south to north, a very small variation takes place in their declination.

The (ascending) node in which the celestial equator and the ecliptic intersect is the First point of Aries, Meṣādi and it gives the 'East'. The second node is the first point of Libra (Tulādi), and these two points never change their declination value (which is zero).

The first point of Cancer (Karkādi) is at a distance of three signs (i.e. 90° and after a distance of three signs more; comes the position of the first point of Capricorn (Makarādi). These give the positions of maximum declination which is 24 degrees.

The solsticial points (which mark the junctions of ayana's) show a movement, and the number of their revolutions in a Kalpa is counted as 199669."

These verses are in Āryāmetre, and they mention the number of revolutions of the 'ayana point' during the Kalpa, which is uncalled for in a Karaṇa work. The author of *Gaṇaka Taraṅgiṇī* states that these verses are not found in the copy of Laghumānasa which is composed in 'anuṣṭup' metre. In the beginning of Laghumānasa there are the following lines **:—

प्रकाशादित्यवत्ख्यातो भारद्वाजो द्विजोत्तमः ।। लघुपूर्वं स्फुटोपायं वक्ष्यन्यल्लघुमानसं ।।

"Bharadwāj, the best of Brāhmaṇas was well known like the sun giving light. I compile another Laghumānasa work which would give accurate results."

It appears from this that Munjāl had compiled another work named Mānasakaraṇa. But Beruṇī observes that the author of Bṛhan Mānasa was one Manu. It is not known if the above verse should be interpreted as "Munjāl after compiling a work Laghumānasa, compiled another work

* Essays *Vol.* II, page 461.

** The description of Laghumānasa given hereafter is based on *Gaṇakataraṅgiṇī*. The author of the *Gaṇaka Taraṅgiṇī* has mentioned the date of Laghumānasa, at some places as Śaka 854 and at some others as Śaka 584. The figure 584 is clearly an error due to oversight, as can be seen from the word "Kṛteṣvibha" (854) occurring at two places in the work as Śaka number and from other proofs also.

Laghu laghumānasa (i.e. a shorter version of Laghumānasa than the one existing before)." The above 'āryas' may form Munjāl's second work entitled 'Laghumāṇasa' or Munjāl himself may have been the author of Bṛhan Mānasa and it might have contained these verses.

The work Laghu Mānasa contains epochal positions of planets true for the noon of Sunday, the first lunar day of the bright half of Caitra, Śaka 854 (elapsed). The planets' places are to be calculated from the ahargaṇa. It contains 8 chapters dealing with the following subjects :— mean places, true places, tithi, three problems, conjunction of planets, solar eclipse, lunar eclipse, and elevation of moon's cusps. The above verse states that Munjāl was a Brāhmaṇa, belonging to Bharadwāj gotra. It is a very important point to note that no available 'human' (pauruṣa) work compiled before Munjāl's time, explicitly mentions the motion of the 'ayana'-point. Munjāl has mentioned a special correction to be applied to the true place of the moon, which is not to be found in any other work. This shows that *Munjāl* was a remarkably ingenious research worker.

The Government Library, Vārānasī, has an incomplete copy of Laghumānasa containing solved examples. In these examples, the Śaka year 1494 has been adopted and the 'Dhruvaks' have been given for śaka 1400. The correction due to ascensional difference and other corrections are applicable with respect to the town of Kāmpilya. According to Sudhākara, the author of this commentary may be Parameśwara, the author of the commentary on Āryabhaṭiya, since the statement that "a commentary has been written on Laghu-Bṛhan Mānasa" occurs in the commentary on Āryabhaṭiya. But this is not probable, because, the author thinks that Parameśwar belonged to Mālābar. The above 'example' shows that Laghumānasakaraṇa was in use till Śaka 15C0 in some territories.

ĀRYABHAṬA II :—It has already been shown (page 188, footnote) that he lived before Beruṇi.

PṚTHU SWĀMĪ :—Beruṇī writes, "Pṛthudak Swāmī is the author of some astronomical work ; but the name of his work is not known to me." It shows that the commentaries written by Pṛthudak Swāmī were not well known in the times of Beruṇī at least in the Sind Province. Beruṇī has quoted a passage from the work of Āryabhaṭa of Kusumpur to the effect that Pṛthudak Swāmī adopted 120 yojanas as the distance of Kurukṣetra from ujjayinī. Since none of the works of the two Āryabhaṭas mention Pṛthudak's name, it seems that this may have been a passage from a commentary on Āryabhaṭa's works. (It appears at many places that Beruṇī was led to believe that the matter occurring in the commentary, belonged to the original text.). The commentary existed before Beruṇī and Pṛthudak lived earlier than the commentary. From this his date may prove to be somewhat between Śaka 850 to 900.

BHAṬOTPALA :—Beruṇī has mentioned some works of this author in addition to those enumerated by the author (page 101). They are :—The Karaṇaworks—Rāhunnakaraṇa and Karaṇapāta, and a commentary on Bṛhan Mānasa. The names of Karaṇa works appear to be curious and the two Karaṇaworks could not possibly have been compiled by one man. Evidently there was some misunderstanding on the part of Beruṇī. He says that Utpala had compiled another work, Śrūdhava by name ; there seems to be some error in the name of the work. Beruṇī has quoted measures of time

etc. as given in these works. He writes that there were still other works named Śrūdhava. He has given some idea of the questions dealt with in them, which suggest that these may be some works on 'omens' or on horary astrology.

KARAṆA TILAK BY VIJAYANANDĪ (Śaka 888)

Beruṇi says that Vijayanandi, the commentator, who was a resident of Vārānasī, compiled the work Karaṇa Tilak. Beruṇi has described the methods of calculating ahargaṇa given in the work, the calculation of mean places from ahargaṇa, finding the discs of the Sun and the Moon for calculating eclipses, calculation of Mahāpāta etc. It contains subjects similar to those of the *Graha Lāghava*, the epochal positions given are true for the first lunar day of Caitra Śukla, Śaka 888. Dr. Sehram writes in his notes that the method of calculating the ahargaṇa is similar to that of the Puliśa Siddhānta. Vijayanandi remarks that stars like Dhaniṣṭhā and Uttarābhādrapadā do not set even when they are in proximity to the sun. The Aufrecht Catalogue does not mention this Karaṇa work. It seems that this Karaṇa work is not at present available anywhere. The Vijayanandi referred to by Varāha Mihira was much more ancient than this Vijayanandi.

BHĀNUBHAṬṬA-BHĀNARJU—He has, according to Beruṇi, compiled a 'tantra' work, named Rasāyana Tantra, and a Karaṇa work entitled, Karaṇa paratilak. Prof. Sachau believes that the author's name may be pronounced as Bhānuraja or even as Bhanuyaśa. Varuṇ's commentary on Khaṇḍakhādya (Śaka 962) has borrowed some Anuṣṭup verses, from *Bhānubhaṭṭa's* work and from the work "Tantra Rasāyana". It is not explicitly stated there that he work "Tantra Rasāyana" was compiled by Bhānubhaṭṭa himself, still, the context, shows it to be so ; and hence, the Bhānuraja (Bhānurajju) referred to by Beruṇi and the Bhānubhaṭṭa referred to by Varuṇa appear to be the same person. His date may be about Śaka 900. The Aufrecht Catalogue does not mention either his name or that of his work. It appears from this that the works are probably not available anywhere at present. The word 'tantra' in 'Tantra Rasāyana' suggests that the work had adopted the method of calculating planets' places from the beginning of the Yuga.

OTHER KARAṆA WORKS—After enumerating the names of some Karaṇa works like the Karaṇa Cūḍāmaṇi, Lokānanda Karaṇa by Lokānanda, Bhaṭṭila Karaṇa by Bhaṭṭila etc. Beruṇi winds up the description with the remark that "there are innumerable such works". This statement of Beruṇi supports the inference that have been drawn before (page 120). It was but natural that several Karaṇa works came into existence according to the needs of different times and places. They are not all available at present, and even if they become available, they would be of no actual use. They will, however, be found useful in tracing the history of our country in general and that of astronomy in particular.

*OTHER WORKS AND AUTHORS BELONGING TO PERIODS LATER THAN ŚAKA 950**

ŚRĪPATI :—Muniśwara's commentary on Līlāvati contains passages from Śrīpati's works which show that he had compiled works on [illegible] and [illegible]. The following lines occur in those passages :—

[illegible]

*This information has been [illegible] mainly from the [illegible].

This describes the method of finding the value of shadow directly from the arcs without making use of tabular sines. Bhāskarācārya has shown the calculation of *chāyā* without sines & arcs, Gaṇeśa Daivajñya has succeeded in carrying out all mathematical work in his *Grahalāghava* without the use of sines & arcs. (see pages 133 to 135). This idea, Sudhākara observes, must have occurred to him from Śrīpati's method. According to Sudhākara, Śrīpati had compiled Ratnāvalī and Ratnasāra, as additional Muhūrta works. The Aufrecht Catalogue mentions Ratnasār. This work may have been an abridged edition of Ratnamālā. The compilation of the other work, Ratnāvalī, does not seem very likely since these two works on Muhūrta were already in existence. Perhaps the work Ratnamālā itself may have been called Ratnāvalī by some people.

KEŚAVA :—Keśava, the author of Vivāhavṛndāvana (page127) has stated in that work, in the verse "Tribhāga śeṣe dhruvanāmni" etc, that the 'vyatīpāta' type of 'mahāpāta yoga occurs when the third part of the "Dhruva yoga" is still to pass. This condition was true when the anyanāṃśas were about 12½°; and in his commentary on the verse Gaṇeśa Daivajñya says, "this has been so stated because, the anyanāṃśas at the time of compilation of the work were 12°". This means that Keśava, the writer of the work, Vivāhavṛndāvana, lived when the ayanāṃśas were 12°, that is, about the Śaka year 1165. The work, in the chapter on Lagnaśuddhi, mentions 4-48 as the *palabhā* of 'Nārmadi' (a city on the bank of the Narmadā). The latitude corresponding to this *palabhā* comes to 21° 48.' The latitude of Broach, a city situated near the mouth of the Narmadā, is 21°-41′. This shows that his place of residence in those days may have been a town on the bank of the Narmadā.

GRAHA SIDDHI BY MAHĀDEVA :—(page 123). The verses in the work, giving the account of his family which have been quoted by the author of the *Gaṇaka Taraṅgiṇī* are correct. They show that the names of his ancestors, from the father backwards were Paraśurāma, Padmanābha, Mādhava and Jojadeva; and he was a resident of Rasin, near the river Godāvarī. The *palabhā* of the place was 4½. There is a village named Rasin situated to the south of Ahmednagar but its palabhā is only 4 and it is not situated near the Godāvarī but near the river Bhima, in Mahārāṣṭra. The opening part of the verses giving his family account runs thus :—

ईश्वरकौवेरजजीदाससमस्तज्जजीप्रजन्मासीत् । श्रीजोजदेवनामा गौतमगोत्रः सदैवज्ञः

From this and from some other clues mentioned before (page 124), he appears to be a Gujerati. Though originally a native of Gujerat, he or one of his anscestors may have shifted to Mahārāṣṭra.

KĀMADHENU KARAṆA BY MAHĀDEVA :—(Śaka 1289)

Mahādeva, son of Bopadeva, a Brāhmaṇa belonging to Kauṇḍinya gotra residing at Tryambak on the bank of the Godāvarī and enjoying an honorable position at the court, compiled the work, Kāmadhenu, which follows the Brahma pakṣa and Āryapakṣa. It contains 35 verses and tables, and it gives the annual motions and epochal positions of planets. It is claimed that the tithi can be calculated by collecting figures from 22 tables.

GAṄGĀDHARA (Śaka 1356)

In the Kali year 4535 (i.e. Śaka 1356), he compiled a tantra work, named 'Cāndramān.' It follows the modern Sūrya Siddhānta. There is a copy of this work in the Government Library Vārānasī. It explains only the methods of calculating mean and true places of planets. It contains nearly 200 verses. The mean positions in it have been calculated from the number of lunar months. But the solar reckoning too appears to have been included in it. Gaṅgādhara used to reside ir the city of Sagar, situated between the rivers Kṛṣṇāveṇī on one side and Bhīmarathī on the other, both of them lying to the west of Śrī Śaila mountain, which is situated on the prime (Ujjayinī) meridian. He was a Brāhmaṇa, belonging to Jamadagnya gotra. The names of his anscestors, from his father backwards were Candrabhaṭa, Bhaṭṭārya and Viṭṭhal. The astronomer, Śrī Candal, was born in this very family. Gaṅgādhara was a follower of the Sūrya Siddhānta. He was in the good graces of the king of Vidyāpur. As "Candramāna-Tantra" was very difficult to understand, his son Viśwanātha recast the work into easily intelligible verses. Viśwanātha's date is not given.

NṚSIṂHA—Rāma, brother of Gaṇeśa Daivajñya, author of Grahalāghava, had a son, named Nṛsiṃha, (page 139). Rāma may have been a younger brother of Gaṇeśa Daivajñya. Sudhākara writes that this Nṛsiṃha compiled in Śaka 1480, a work entitled "Madhya-graha-siddhi" on the lines of Mahādeva's work "Graha-siddhi". It explains the calculation of the mean places only. The true places are further to be calculated with the help of Mahādeva's work. Kṛṣṇa Śāstrī Goḍbole observes in his Marāṭhī manuscript : "Nṛsiṃha, son of Rāma and grandson of Keśava Daivajñya. compiled a work entitled Graha Kaumudī in Śaka 1510. The date of birth of Nṛsiṃha is Śaka 1470". One of the two dates, this one and Śaka 1480, mentioned above, must be erroneous. Since Nṛsiṃha says that the planets places should be obtained after multiplying the difference between the given year and Śaka 1480 by the annual motiins, the latter date cannot be wrong. Nṛsiṃha may perhaps have compiled this work some years after Śaka 1480.

CHAPTER 2

THE UNIVERSE

A general description of the Universe has been given in the INTRODUCTION (page XXIX of Part I) Now let the subject be discussed in greater details.

It has already been told (page XXXI of Part I) that the motion of planets in their orbits has been assumed to be the same, and it is about 11858¾ yojanas in one day. And it is also assumed that each planet travels in one Kalpa a length equal to the circumference of the circularring of the celestial sphere. In other words, the length of the celestial orbit* is equal to the sum of the orbital lengths of the revolutions made by each planet in one Kalpa. Hence, the length of a planet's orbit is obtained by dividing the length of the orbit of the celestial sphere by the number of revolutions made by each planet in one Kalpa. The Sūrya Siddhānta gives the measures of orbital lengths as follows :—

*The orbit is really that path in the sky along which a planet appears to revolve round the Earth. The word "celestial orbit," however, does not convey that meaning. As a matter of fact, the celestial orbit has no independent existence. It has been assumed only to facilitate the calculation of the lengths of planetary orbits.

Planet	Orbital length in Yojanas.	Planet	Orbital length in Yojanas.
Moon	324000	Jupiter	51375764
Mercury's mean elongation	1043209	Saturn	127668255
Venus's mean elongation	2664637	Starry belt	259890012
Sun	4331500	Celestial sphere (sky)	18712080864000000
Mars	8146909		

MOON'S DISTANCE FROM THE EARTH

All the siddhānta's except the first Ārya-Siddhānta, give the same daily motion, in yojanas, to the planets. Still, as the number of days in the Kalpa vary with each siddhānta, the length of the celestial orbit and those of the planets also differ by a small quantity. It would be of no use to give all these figures, since they contain very little truth. Most of the data are merely imaginary. The moon's orbit, however, has not been determined by imagination. There is a great degree of truth in it. The length of 1′ arc of moon's orbit in its plane, has been assumed to be equal to 15 yojanas by all except Āryabhaṭa I. Hence the length of the complete orbit comes to $(360 \times 60 \times 15) =$ 324000 yojanas; and the mean radius vector of the orbit comes to 51566 yojanas. This is the moon's distance from the Earth. The radius of the Earth, according to the Sūrya Siddhānta, is 800 yojanas; hence, the moon's distance from the Earth is 64·46 times earth's radius. According to modern discoveries it is 50·96 times earth's radius. The distance of the moon from the earth and its orbital length, as determined by the authors of our siddhāntas are so very near the truth that they deserve to be congratulated on having been able to establish such a correct measure.

The motions of planets in their respective orbits have been assumed to be the same and the lengths of orbits are found by dividing the length of the celestial orbit by the number of revolutions of planets in the Kalpa. This amounts to assuming that the times required by planets to revolve in their orbits are proportional to their orbits, that is, to the distances of planets from the Earth. But this is not true according to the modern astronomical theory. The modern theory established by Kepler and confirmed by NEWTON and others is that the square of the revolution period of the planet is proportional to the cube of its distance from the Sun.

DISTANCES OF PLANETS FROM THE EARTH

The distance of the Sun from the Earth comes to [illegible] yojanas according to the Sūrya Siddhānta, i.e. [illegible] times the Earth's radius. But according to modern discoveries, it is [illegible] times the radius of the Earth. The distances of planets farther than the Sun, as given in our siddhāntas, are still

more erroneous. Our astronomers have not determined — lengths of planetary orbits and the periods of their revolutions after first determining the length of the *Celestial orbit* and the mean daily motions of planets in their respective orbits in terms of Yojanas, by actually taking observations. It is quite clear that they first determined the periods of revolutions and the length of the moon's orbit by observation, and then, on the basis of these figures they fixed the lengths of the planetary orbits and that of the circumference of the celestial sphere. The Pañca Siddhāntikā does not mention the lengths of the orbits of planets and that of the circumference of the celestial sphere in terms of yojanas nor does it mention the length of the moon's orbit; it appears, therefore, that the original Sūrya Siddhānta never contained this information. The modern Sūrya Siddhānta does give these measures ; and the author has arrived at the conclusion that the modern Sūrya Siddhānta existed before the Pañcasiddhāntikā. It is not, however, improbable that the lengths of planetary orbits may have been interpolated afterwards*. Secondly all the siddhāntas except the first Ārya Siddhānta have given 15 yojanas as the length of the moon's orbit subtended by one-minute angle. Thirdly the positions of planetary orbits are fixed, and the planets always move through them. The places of the orbits do not change. Hence, the statement that all planets make a revolution of the sky only once in a Kalpa has no meaning. Bhāskarācārya plainly remarks,

ब्रह्मांडमेतन्मितमस्तु नो वा कल्पे ग्रहः क्रामति योजनानि ॥

यावंति पूर्वैरिह तत्प्रमाणं प्रोक्तं खकक्षाख्यमिदं मतं नः ॥१॥

सि. शि. कक्षाध्याय.

"The Universe may or may not be limited by the *Celestial orbit*. It is the writer's opinion that earlier astronomers have defined "the circumference of the celestial orbit" as equal to the total length in yojanas moved through by a planet in a Kalpa."

Our astronomers fixed the lengths of the planetary orbits from that of the moon and the time taken by each planet for making one revolution. The principle, assumed as basis, that the time of a revolution and the length of the orbit are in proportion, was not true, and hence, the measures of orbital lengths have proved to be wrong while the length of the circumference of the *celestial orbit* is found to be utterly fictitious.

Although the measures of orbital lengths and consequently the planetary distances from the centre of the solar system are erroneous, as explained above, still the radii vectors of planets which are their distances from the centre of the solar system, mostly agree with their modern values, when calculated on the basis of the correction known as annual parallax whose values are given in our ancient works and which in fact are the variations affecting their true places as the result of these distances. This will be seen from the subjoined table in which the measures given by

*An ancient work like the Brahma Siddhānta compiled in Śaka 550, does give these measures. Hence, if these measures have found an entry into the Sūrya Siddhānta later, they may have done so any time after Śaka 550.

*Ptolemy** are also noted :

Planet	Sūrya Siddhānta even quadrant	Sūrya Siddhānta odd quadrant	Ptolemy	Modern
Sun (or Earth)	1	1	1	1
Mercury	·3694	·3667	·3750	·3871
Venus	·7278	·7222	·7194	·7233
Mars	1·5139	1·5517	1·5190	1·5237
Jupiter	5·1429	5·0000	5·2174	5·2028
Saturn	9·2308	9·0000	9·2308	9·5388

The measures calculated from the Sūrya Siddhānta have been given above. The radii vectors of Mercury and venus are calculated by dividing the length of the circumference of the epicycles of conjunctions** by the lengths of the planetary orbit *i.e.* by 360 and those of the Superior planets by dividing 360 by the circumferences of the epicycles of conjunctions.

It has been remarked above that the length of the moon's orbit according to Āryabhaṭa I is different. It is obtained as follows :

शशिराशयष्ट १२ चक्रं तेंशकलायोजनानि य ३० व ६० अ १० गुणाः ॥ ४ ॥

दशगीतिकापाद.

"The length of moon's orbit in yojanas is given by multiplying the total number of signs (*i.e.* 12) by 30, 60 and 10".

In this it is stated that the number of minutes of arcs in the moon's orbit multiplied by 10 gives the length in yojanas. In other words, here 1′ arc is taken to be equal to 10 yojanas, while other siddhāntas have taken it to be equal to 15. This appears to be contradictory to other siddhāntas at first sight, but in fact, there is no contradiction. The following table will show that just as the length of the moon's orbit given in other siddhāntas is 3/2 times that given by Āryabhaṭa I, so also are other measures :—

	Yojanas according to First Āryasiddhānta	Yojanas according to Siddhānta Śiromaṇi
Diameter of the Earth	1050	1581
" Sun's disc.	4410	6522
" Moon's disc.	315	480

* Ptolemy's figures have been taken from the translation of the Sūrya Siddhānta by Burgess, and the modern measures from the work of Loomis.

** The lengths of circumferences of the aphelia and the perihelia have been mentioned later on. The question will be discussed at greater length later on in the chapter on true places.

It is stated in the verse that some worlds remain in position because of the support of the wind. But it is not clearly stated that planets and stars are worlds. It appears that our astronomers did not have the idea that planets and stars are very heavy and expansive globes like our earth.

ATTRACTION

Bhāskarācārya has assumed that the earth possesses the power of attraction. He says,

आकृष्टिशक्तिश्च मही तया यत् खस्थं गुरु स्वाभिमुखं स्वशक्त्या ।।
आकृष्यते तत्पततीव भाति ।। ६ ।।
गोलाध्याय, भुवनकोश,

"The earth possesses the power of attraction. It pulls towards itself a heavy body in the sky and the latter appears to fall."

The falling down of a body is here stated to be due to attraction. When Newton discovered the power of attraction possessed by the earth, what thing other than the falling down of a body to the earth, could have suggested to him the power of attraction possessed by the earth ? He drew the inference that the planetary system revolves round the Sun on account of this power of attraction, and established the law of gravitation, after proving it mathematically ; this further work (of research) was, however, not taken up in our country.

DESCRIPTION OF THE EARTH

All siddhānta works while describing the Universe, give a description of the seven oceans on the earth and seven continents along with mountains and rivers in them ; but this, in fact, forms part of Geography, and hence, the author does not deal with it here for want of space.

VIEWS OF THE SKY

As regards the views of the heavenly bodies observed from different places on the earth, it may be stated that the Pole star appears to be in the horizon when observed from any place on the Equator, and the planets and other celestial bodies appear to rise and set along a vertical circle. As one goes northwards, the north pole appears to attain higher altitudes, and the diurnal circles along which planets and other bodies appear to move, are seen inclined to the horizon. For an observer at the pole, the Sun and other (celestial) bodies, appear to move along circles parallel to the Equator ; all these things are discussed in the Siddhāntas. The author does not give quotations from the original here for want of space.* Again, most of the Siddhāntas discuss questions like these (i) what places in the northern hemisphere (*i. e.* places in what latitudes) can never see a particular portion of the ecliptic, (ii) what latitudes can never see certain signs of the ecliptic or (iii) what are the latitudes where the Sun is visible for 60 ghatis or even more, and for how many days. It is not necessary to repeat them here in detail.

* The Marathi book entitled *Bhāskarācārya ani tyāncha Jyotiṣa* (Bhāskarācārya & his astronomy) by J. B. Modak contains such quotations from Bhāskarācārya in the original along with their translation.

REVOLUTIONS OF PLANETS

The cause of mean motions of planets has already been discussed above. The numbers of the revolutions of planets in the Zodiac during the period of one Kalpa or one Mahāyuga have already been given as mentioned by different siddhāntas. There is a noteworthy point about Mercury and Venus ; and it is that because they are always found near the Sun, their revolutions in the Zodiac are assumed to be always equal to those of the Sun ; and hence, our authors of the works have assumed for them the same number of revolutions and mean motion as for the Sun. But having regarded the conjunction (Śīghra) of Mercury and Venus as some planets, the numbers of their revolutions given by them in the works happen to be equal to those of their actual revolutions round the Sun ; and although our astronomers had no idea that planets revolve round the sun, it is worth remembering that they had given importance to the revolutions of the 'Śīghras' of Mercury and Venus.

LIGHT OF PLANETS

It is the view of our Astronomical science that planets have no light of their own, but that they receive it from the Sun. Āryabhaṭa I observes

भूग्रहभानां गोलार्धानि स्वच्छायया विवर्णानि ।।
अर्धानि यथासारं सूर्याभिमुखानि दीप्यन्ते ।। ५ ।।

गोलपाद

"Half the spherical portions of the earth, the planets and the stars lose their light in their own shadows. Their faces which are towards the Sun are illuminated in the proportion in which they are so directed."

In this verse it is stated that even the stars receive light from the Sun, which is a mistake. A great deal of discussion is, found in our works regarding the increase or decrease of the Moons' digits, and the elevation of Moon's cusps.

VIKṢEPAS OF PLANETS

The vikṣepas of planets which are the inclinations of their orbits with the ecliptic are given in some siddhāntas in the chapter on mean motions. Therefore, the measures of different siddhāntas are given here—

Ptolemy's values and the modern ones are also given* in this table.

	Modern Sūrya Siddhānta		I Ārya S. Lalla's S.		Brahma S, Sid.Śiro.		II Ārya Siddhānta		Ptolemy		Modern		
	°	′	°	′	°	′	°	′	°	′	°	′	″
Moon	4	30	4	30	4	30	4	30	5	0	5	8	47.9
Mars	1	30	1	30	1	50	1	46	1	0	1	51	2
Mercury	2	0	2	0	2	32	2	18	7	0	7	0	7.7
Jupiter	1	0	1	0	1	16	1	14	1	30	1	18	41.4
Venus	2	0	2	0	2	16	2	16	3	30	3	23	34.9
Saturn	2	0	2	0	2	10	2	10	2	30	2	29	39.5

* The author has taken Ptolemy's values as given by Burgess in his translation of Sūrya Siddhānta and the modern values are taken from Leverrier's Tables.

Mars and Jupiter are concerned, have given values nearer to the modern ones than those of Ptolemy. The values given in Brahma Siddhānta and Second Ārya Siddhānta are almost equal to the modern ones. The value for Saturn is wrong by a few minutes only. As regards the Vikṣepa values of Mercury and Venus, it was found that if Mercury occupies at present a position of maximum heliocentric latitude, then, at one position its radius vector attains the value of ·3382 and at the other, ·4114*, and if in addition to this, its distance from the earth has attained the mean value, its true latitude respectively becomes 2°23′′ and 2°53.′ The mean of these values comes to 2°38′ and it agrees very closely with that given in our works. The radius vector of Venus at its position of maximum heliocentric latitude attains the values of ·7193 and ·7293. If at both these positions its distance from the earth attains the mean value, its true latitude would be about 2°28′. This also agrees with the value given in our works. The values given in the table in the column for "modern" values, were calculated by the author from the data in the English *Nautical Almcnacs* for the six years 1883 to 1888. It was only on two or three dates during these six years that when Mercury attained maximum value for its heliocentric latitude, its distance from the earth was also equal to or very nearly equal to its mean value ; and in the case of Venus no such dates could be found. It shows that these values cannot be accurately found unless observations are taken for several years ; and for this reason our astronomers deserve praise for having found out very accurate values. The nodes of planetary orbits have got some slight motion. Hence, if the maximum values of the latitudes of planets at the time of Brahmagupta and Āryabhaṭa be calculated in the light of modern mathematics' the above Siddhānta values may perhaps prove to be nearer to the true values** than what we found in this comparison. The above verses will show that the values given by the two Āryabhaṭas are different from those given by Brahmagupta and this shows that the values have been found by them independently. It cannot be argued that the figures are different in the three cases because they have been set down at random. If no other proofs be forthcoming, even the Vikṣepa values given in the above table would be enough to show that our astronomers determined the values for inclusion in their works, actually after taking observations.

CHAPTER III

"AYANA CALANA"

OR

DISPLACEMENT OF SOLSTITIAL POINTS

Even if at a certain time, a star is found to be situated near that point of the ecliptic, which is crossed by the Sun and the Moon while moving from North to South and vice versa, it will not remain there for all time to come ; it will be seen shifting eastwards as years roll by. At the time of the *Vedāṅga Jyotiṣa* the Winter Solstice (W.S.) used to occur near the beginning of Dhaniṣtha : but as time passed on, it began to take place near Śravaṇa. At

*The mean radius vector of Mercury is ·3871 and that of Venus is ·7233 (Loomis Practical astronomy).

**A mere recording of the values of Vikṣepa as given in our works and the modern ones side by side does not amount to a real comparison. The writer has not seen any one comparing the latitude values of Mercury and Venus as he has done above.

the time of Varāhamihira it used to occur near Uttarāṣāḍha. This means that the solstitial point receded so many degrees. If one point of the ecliptic changes its place, all points on it would necessarily do the same thing. Consequently, the star which at one time would be situated near the equinoctial point, which is the point of intersection of the equator with the ecliptic, would be seen to have shifted its place forward as time would pass ; but in fact, it is the equinoctial point which recedes. As the change in the position of solstitial point was first noticed by astronomers while observing the sun's 'ayana' i.e. the solstitial position, most of the astronomical works have termed this kind of change as "ayana calana". The astronomer ĀRYABHAṬA II and others have mentioned the number of revolutions of the 'ayana,' as if it were a planet. BHĀSKARĀCĀRYA has called this motion also 'Sampāt-calana' i.e. the shifting of equinoxes, while the European astronomers call this phenomenon "precession of the equinoxes". All astronomical works except that of Bhāskarācārya have attributed this motion of solstitial points to the movement of the 'starry wheel'. In other words they thought that the starry wheel moves eastward through some degrees in some particular period of time. But Bhāskarācārya observes :—

तस्य [विषुवत्क्रांतिवलयपातस्य] अपि चलनमस्ति । येऽयनचलन-
भागा: प्रसिद्धास्त एव विलोमगस्य क्रांतिपातस्य भागा: ।।

गोलबंधाधिकार.

"Even that point (viz. the point of intersection of the equator with the ecliptic) has a shifting motion. The equinox recedes through as many degrees as the solstitial points".

This evidently shows that he assumes a retrograde motion for the node (i.e. the equinoctial point) itself. Even the modern European scholars hold that it is the equinoctial point which has this motion of displacement.

MEASURE OF DISPLACEMENT OF SOLSTITIAL POINTS

Varāhamihira has mentioned nothing about the 'ayana-calana' in his Pañca Siddhāntikā. It appears that the five old siddhāntas had mentioned nothing about it. But the modern Sūrya Siddhānta does mention it. It has been described there as follows :—

त्रिंशत् ३० कृत्यो २० युगे भानां चक्रं प्राक् परिलंबते ।। तद्गुणाद्भूदिनैर्भक्तात्
द्युगणाद्यदवाप्यते ।।

तद्दोस्त्रिघ्ना दशाप्तांशा विज्ञेया अयनाभिधा: ।। तत्संस्कृताद् ग्रहात्
क्रांतिच्छायाचरदलादिकं ।। १० ।।

स्फुटं दृक्तुल्यतां गच्छेदयने विषुवद्वये ।। प्राक् चक्रं चलितं हीने छायार्कात्
करणागते ।। ११ ।।

अंतरांशैरथावृत्य पश्चाच्छेषैस्तथाधिके ।।

त्रिप्रश्नाधिकार.

follows that according to the Sūrya Siddhānta that the equinox does not make a complete revolution through the Zodiac, as the planets do. In other words, the starry wheel moves away from the equinox up to 27° towards the east, then comes to its original position, then moves westward up to 27° and then again comes to the original position. It thus completes an oscillatory revolution, each amounting to 108°. According to modern astronomy the correct motion of the precession of equinoxes is about 50.2 seconds per year. If we adopt a revolution consisting of 108° each and 30 such revolutions per mahāyuga, the annual rate of precession would come to about 2 $\frac{7}{10}$ seconds, which is extremely small. Even if we take 30 true revolutions of 360° each, the annual rate of motion would come to only 9 seconds, which is also very small. If we take the present reading 'triṃśatkṛtyaḥ' to mean 600 revolutions of 108 degrees per Mahāyuga, it would give 54 seconds per year, and this is now the generally accepted interpretation. This rate is much more correct; but all current works on astronomy have assumed 60 seconds as the annual rate of motion, and the author has shown later on how this value is the proper one and acceptable. If one takes 600 revolutions of 360 degrees each, the annual rate of precession would come to be 180 seconds. This would be a very excessive rate.

The modern Romaśa, Soma and Śākalyokta Brahma Siddhānta give 600 revolutions of the 'ayana' in one mahāyuga. Their remarks about the displacement of the ayana point are given below :—

गुणः षट्शतघ्नोऽर्कशुद्धोदयहृतो ग्रहः ॥ ३१ ॥ आयनसिध्यतद्बाहुभागा दिग्भिर्विभाजिताः ॥
अयनांशास्तदूर्ध्वाधं धनं पूर्वंबले ऋणं ॥ ३२ ॥

रोमशसिद्धांत, स्पष्टाधिकार

इत्येतस्मेतत्प्राक्चलनं युगे तानि च षट्शतं ॥ १६६ ॥ युक्तयायनग्रहस्तस्मिन् तुलादौ
प्राक् चलं भवेत् ॥

पश्चात् तत् शुक्लपक्षे वा मेषादौ प्राक् चलं भवेत् ॥ १६७ ॥ अयनांशास्तद्गुणांशाद्विघ्नाः
संतो दशोद्धृताः ॥

शाकल्यब्रह्मसिद्धांत, अध्या २

युगे षट्शतकृत्वो हि भचक्रं प्राग्विलंबते ॥ तद्गुणो भूदिनैर्भक्तो युगणोयनखेचरः ॥ ३१ ॥
तद्भुजांशकलीलिप्ता द्विशत्याप्तायनांशकाः ॥ संस्कार्या जूकमेषादौ केंद्रे स्वर्णं ग्रहे किल ॥३२॥

सोमसिद्धांत—स्पष्टाधिकार

All the three verses convey the same idea as that expressed by Bhāskara. The only point of difference is that in Śākalya's verse the 'ayana-graha' is supposed to move east from the beginning of Libra and towards West from that of Aries.

The Vasiṣṭha Siddhānta (also called Laghu Vasiṣṭha Siddhānta by some) describes the method of calculating Ayanāṃśa as follows :—

[illegible] ॥ ११ ॥

स्पष्टाधिकार

"Divide the number of years elapsed by 600, reduce the result to an acute angle nearest to a quadrant, multiply the degrees by 3 and divide by 10, the result thus obtained will be ayanāṃśas.,"

It is not here clear what we get after dividing 'n' years by 600, does the quotient denote so many signs, degrees or revolutions ? If we assume recession through one sign in 600 years, it would give 600 revolutions in a Mahāyuga and that seems to be the number intended.

This shows that the later five Siddhāntas, including S.S., have regarded 27° as the maximum value of ayanāṃśa and that the equinox has been regarded as oscillating from the initial point to 27° East and then back again, till it attains a position 27° West and so on, giving 54 seconds per year as the precessional motion.

Aryabhaṭa I and Lalla make no reference to the ayana-motion in their works. Brahmagupta, while accusing Śriṣeṇa and Viṣṇucandra, says,

परमाल्पा मिथुनान्ते द्युरात्रिनाडयो ऽर्कगतिवशादृतवः ॥ नायनयुगं............॥ ५४ ॥

अध्याय ११

"The very fewest hours of night occur at the end of Mithuna, and the seasons are governed by the Sun's motion ; there is, therefore, no such thing as ayanāṃśa". Pṛthūdaka in his commentary on the above verse says, "What is said by Viṣṇucandra at the beginning of the chapter on the Yuga of the solstice 'Its revolutions through the asterism are here (in the Kalpa) 189411. This is termed a Yuga of the solstice, as of old admitted by Brahma. Arca, and the rest" is wrong. Now the greatest decrease and increase of night and day do not happen when the Sun's place is at the end of the Mithuna ; and passages are remembered expressing "the southern road of the sun was from the middle of Aśleṣā ; and the northern one at the beginning of Dhaniṣṭhā; and others (of like import). But all this only proves that there is a motion ; not that the solstice has made many revolutions through the asterisms".

Bhāskarācārya while commenting on Brahmagupta's notions about Ayana motion, says :—

तत्कथं ब्रह्मगुप्तादिभिर्निपुणैरपि [क्रांतिपातः] नोक्त इति चेत् तदा स्वल्पत्वात् तैर्नोपलब्धः।

इदानीं बहुत्वात् सांप्रतैरुपलब्धः। अतएव तस्य गतिरस्तित्यिवगतं। यद्येवमनुपलब्धोपि सौरसिद्धांतोक्तत्वादागमप्रामाण्येन भगणपरिध्यादिवत् कथं तैर्नोक्तः····

"If doubt be expressed as to how it was that skilled scholars like Brahma gupta and others did not mention the precession of the equinox, the reply is that they could not notice it because of its very small amount. It has been now noticed because of a noticeable displacement and hence, it has now been realised that the equinox has motion. It may be asked, that even though it was not noticed, why was it not given on the authority of the figures mentioned in S.S. just as the numbers of revolutions, Paridhis etc. have been taken from Āgamas." ?

Bhāskara says here, that at the time of Brahmagupta, the ayanaṃs value was very small and hence it is likely that it could not have come to his notice and adds that one may still ask why he did not take the rate of the precessior of equinoxes as given by S.S., just as he had taken figures for other measures on the authority of older authors.? It is true that Brahmagupta nowhere mentions any correction on account of precession or gives any figure as the number of yana revolution, yet the above verses of Brahmagupta and Pṛthūdaka's commentary thereon clearly point to the fact that people before the time of Brahmagupta had begun to think over the problem of change in Ayana position. According to Brahmagupta the Sun's entry into a tropical sign was a 'Saṃkramaṇa', and the "end of Sāyana Mithuna" was the Summer Solstice. (This has already been shown in authors' account of his works). Hence he has not at all taken into account the equinoctial motion.

Munjāl's quotations in Āryametre have already been given (H page 191).. The number of revolutions of the 'ayana' have been mentioned therein to be 199669. These couplets make no mention of the question whether the equinox makes a complete revolution or not. But assuming that the equinox makes a complete revolution, the explement of the longitude of the equinox would come to $9^s\ 29^\circ\ 37'\ 40''.8$ at the beginning of Kali era, the ayanāṃsa would be zero in Śaka 449, and the annual rate of the precession would be $59''.9007$. All these things clearly point to the fact that Munjāl held the view that the equinox made a complete revolution.

The Laghumānasakaraṇa of Munjāl written in Śaka 854, gives I′ as the annual motion for precession.

The second Āryasiddhānta gives the revolutions of the ayana planet for Kalpa and describes in the following verse the method of finding ayanāṃśa,

अयनग्रहदो:क्रांतिज्याचापं केंद्रवद्धनर्णं स्यात् ॥
अयनलवास्तत्संस्कृतखेटादयनचरापमलग्नानि ॥ १२ ॥

स्प टाधिकार.

Meaning :—"Reduce the longitude of the 'Ayana planet' to an angle less than 1 rt. angle. Find out the sine of the angle. The value is Ayanāṃśa. The sign corresponds to the sign of the 'anomaly'. (It is positive if the Ayana planet be in one of the first six signs, otherwise negative*). After applying this correction to the planet, the values of Ayana Caraṇ (ascensional differences or A.D., Krānti (declination) and Lagna (ascendant) etc. are to be calculated". This is similar to the method of calculating a planet's declination. All our Siddhāntas and even the Second Ārya Siddhanta regard 24° as the maximum value of declination. Hence according to Āryabhaṭa II, the ayanāṃśa value never exceeds 24°. In other words, the "plus" ayanāṃśa figures increases from 0 to 24 degrees, then it diminishes up to zero. It further becomes negative and increases from 0 to 24 degrees, and again begins to diminish till it becomes zero. The equinox is to be supposed to be making a revolution through 96 degrees.

*This convention about positive and negative signs has occurred in connection with planets in this very chapter.

According to the Second Ārya Siddhānta the number of revolutions of Ayana planet during a Kalpa are "masihaṛamudhā*" i.e. 578159. Taking one revolution as equal to 96° the annual rate of precession would come to 46.3 seconds ; but since, the method of calculating ayanāṃśa is exactly like that of calculating declination, the rate of precession will not always be the same. Adopting the above mentioned number of revolutions, the yearly rate of motion of the Ayana planet in the Zodiac would come to 2 min. 53.4 seconds, and the annual rate of precession would sometimes come to 69.4 seconds, sometimes to 6.1 sec. or even less. The Ayana planet takes about 7472 years for one revolution. The rate of precession during the 10th part of the 1st period i.e. during first 187 years, would be 69.4". During the next 187 years it would be almost the same. In the 3rd period of 187 years it will be 63.7". It will thus gradually come to be 58.1", 52", 43.3" ; 30.6", 20.4" and 6.1". When thus the ayanāṃśas reach the figure of 24 degrees, they will diminish in value at a reversed rate of motion, they will again increase and will again decrease ; but our experience is otherwise. The ayana-motion no doubt varies ; but the variation is very slight. There is no harm if it be regarded as always constant.

Āryabhaṭa II has, like Parāśara, cited 581709 as the number of ayana revolutions in a Kalpa. According to this hypothesis Śaka 532 would be the Zero-precession year ; and because ayanāṃśas are calculated by the method of calculating declinations, their value is never constant ; their mean value comes to be 46".5..

Bhāskarācārya has not given the number of revolutions of the equinox in a Kalpa, nor has he given his view** whether the equinoctial point makes a complete cycle or makes an oscillatory cycle of 108°. It has been pointed out above that he has adopted the number of revolutions given in the S.S. He further says,

अयनचलनं यदुक्तं मुंजालाद्यैः स एवायं (क्रांतिपातः) ॥
तत्पक्षे तद्भगणाः कल्पे गोंगर्तुनंदगोचंद्राः १९९६६९ ॥ १८ ॥

गोलबंधाधिकार.

"The displacement of the solstitial point, spoken of by Munjāl and others refers to this very point (viz. equinox). Its revolutions in one Kalpa are 199669.

After quoting the ayana revolutions according to S.S. and Munjāl, in his commentary on the above verse he next observes".

अथ च ये वा ते वा भगणा भवंतु यदा येंशा निपुणैरुपलभ्यंते तदा स एव क्रांतिपातः ।

"Whatever be the number of revolutions, the degrees which are obtained by skilled (astronomers) give the position of the equnox."

It is clear from this that he recommends one to accept the ayanāṃśas which one would actually get by observation at a particular time. Similarly, his remark in this connection that "any motion which one gets actually by observation should be accepted", shows that he means to say that the number of revolutions in a Kalpa should be determined according to the ayanāṃśas actually found. The author has not come across a single statement in which Bhāskarā-

*The number has been fixed after fully considering the variations in readings.

**Prof Whitney observes that Bhāskrāchārya has mentioned 199669 as the number of revolutions of the equinox in one Kalpa (See page 104 Trans. of S.S.). But it is a mistake. Bhāskarācārya has given this number as that mentioned by Munjāl.

cārya has clearly said that the equinoctial point makes a complete revolution, nor does he say that it does not make a complete revolution. Bhāskarācārya has taken 1 minute per year as the ayanamotion in the work Karaṇa-kutūhala and has assumed 11° as the ayanāṃśa in Śaka 1105. He thus appears to have taken Śaka 445 as the Zero-precession year, as has been already mentioned before.

From the foregoing discussion of the question of ayana revolution and yearly ayan-motion it can be concluded that according to (*i*) the five Siddhāntas such as the S.S., the annual precessional motion was 54″ (*ii*) Munjāl, 59″.9 (*iii*) Ārya bhaṭa II 46″.3 and (*iv*) Parāśara 46″.5. However, it would not be wrong to say that since Śaka 854, the annual precessional motion was 60 seconds for all practical purposes, and most of the Karaṇa works compiled from that date upto now have given this rate for the ayana motion. The Bhaṭatulya-karaṇa and one or two karaṇa-works following S.S. have, however, adopted 54 seconds as the motion.

Does the Equinoctial Point Oscillate or Revolve ?

The question whether the equinox makes a complete revolution or not has been fully considered above. According to Munjāl, the equinox makes a complete round in the ecliptic in a retrograde direction. As already mentioned Colebrooke says that Pṛthūdaka, the commentator of Brahma Siddhānta, and Nṛsiṃha, that of Śiromaṇi, have quoted Viṣṇucandra, the author of Vasiṣṭha Siddhānta, as believing in the theory of the complete revolution of the equinox. According to the five modern Siddhāntas, including the S.S., the equinox does not make a complete revolution but it oscillates upto 27° east and west of Revatī while according to Second Ārya-Siddhānta it oscillates up to 24° only. Although none of the Karaṇa works explicitly states that the equinox makes a complete revolution, the method of calculating ayanāṃśas adopted would give more than 24° or 27°, that is amounts increasing right up to 360°. No karaṇa work probably states that when the ayanāṃśas come to be more than 24° or 27°, the rate of motion should be supposed to be minus 60″, or in other words, the ayanāṃśas should be supposed to be gradually less than 24 or 27 degrees. In accordance with Karaṇa works which assume Śaka 445 as the Zero-precession year and 60″ as the annual rate of precession, the ayanāṃśas would be 24° in Śaka 1885 and 27° in Śaka 2065. They will be 27° in Śaka 2221 if S.S. be followed, and according to Āryabhaṭa II and Parāśara they will be 24° in about Śaka 2400. So the question whether the theory that the displacement of ayana-point does not take place through the whole Zodiac is valid would be settled by actual experience after about 67 years or after 600 years at the most. The modern theory of European astronomers that the equinox makes a complete revolution is a well known fact and if this theory be correct the rainy season will be found to occur in Caitra-Vaiśākha after a lapse of time. No one will be able to deny the contention of the followers of the sāyana system in this respect and the occurrence of spring during the months of Madhu & Mādhava (*i.e.*, Caitra-Vaiśākha) is the only thing acceptable to the Śrutis. Fearing that the acceptance of Munjāl's view would take them into a position contradictory to that approved by the Śrutis, the author of Marīci & others accused Munjāl and others for holding views contrary to the teaching of the Vedas, and they were, in their own way, right in doing so. But it is not within our control to force the equinox to make a complete or incomplete revolution; this point did not strike the author of Marīci and others. The Vedāṅga jyotiṣa has recorded the occurrence of the Winter solstice (W.S.) in the beginning of Dhaniṣṭha. From this it appears that in those days, the equinox used to occur in the beginning of the fourth part of Bharaṇī conste-

lation, *i.e.*, at a point 23° 40″ from the intial point. The Vedas describe the Zodiac as beginning from the Kṛttikās, which suggests that the equinox used to occur in the beginning of Kṛttikās then, *i.e.*, at a point 26° 40″ from the initial point. Formerly the equinox was in advance of Aśvinī, and later on it began to occur behind it. This may have suggested that the equinox oscillates, and because the displacement of equinox which was recorded was only a variation of 24 or 27 degrees, or because the maximum declination is 24°, some of the authors of siddhāntas may have been led to assume that the equinox oscillates up to 24 or 27 degrees. Let, future experience show what it may be, but the theory of oscillation of equinoxes proved very useful in tiding over the temporary difficulty of admitting that the seasons would not conform to the teaching of Śruti as the result of the complete revolution of the equinox.

ACCURACY OF AYANA MOTION

Let us now see how far the annual rate of ayana-motion and the year of zero-precession are accurate, as adopted by our astronomers. The annual ayana-motion is clearly the advance made by the Sun in the assumed length of the year after its two successive transits of the equinox. The lengths of years given by different siddhāntas have been fully discussed on page 13 while reviewing the Romaka Siddhānta of the Pañca Siddhāntikā group. The lengths of year known to Vedānga Jyotiṣa, Pitāmaha and Puliśa had already gone out of use before the year Śaka 427 (*i.e.*, before Pañca Sidddhāntikā). It has already been pointed out there that Romaka's year was never in use in our country. Of other Siddhāntas, the length of Brahmagupta's year *viz.*, 365^{d}, 15^{gh} 30^{p} $22\frac{1}{2}^{v}$ does not appear to have remained in use after Śaka 964. The remaining lengths vary from 365^{d} 15^{gh} 31^{p} 15^{v} to 365^{d} 15^{gh} 31^{v} 31^{g} 24^{pv} and have remained in use from Śaka 1000 onwards. The length of the tropical year in the year 1900 A.D. is 365^{d}-14-31-53-25. This is the time taken by Sun to return to the same equinox. If we deduct this from the length given by S.S. viz. 365-15-31-31-24, the motion of the Sun during the difierence of time would come to 58″.777* or 58″.8 approximately. If we accept the shortest of the lengths of the year in use from 1000 A.D., the annual "ayana-motion" would be less by .269 i.e. about 58″.508. If Brahmagupta's year measure be accepted, it would come to 57″.557 but the author is of opinon** that the above year measure was not taken as the basis while fixing the yearly rate of ayana-motion. It is a fact that the measure of the tropical year is gradually diminishing. If we accept the length of the tropical year in Śaka 700 as basis, all the above-'ayana-motions' will have to be reduced by about 0″·24. All things considered, if the annual rate of precession 58″.4 be accepted, it will be found to be very accurate, since it is in keeping with the average length of the year adopted in our works, and both Grahalāghava and Makaranda which are in use in more than half of India, adopt the length of the year given by moderr S. S. Hence, the rate of precession dependent upon this year length which comes to 58″.6 should be considered accurate. This will show that the figure of 59″.9 adopted by Munjāl as the annual rate of motion and 60″ which is now in general use, appear to be sufficiently accurate.† In other

* Keropant has mentioned 58″.521 (see Planetary Tables page 32,); but a small error seems to have crept in here.

**The reason is given on page 216 later on.

†The difference in the place of the tropical sun computed by European measures and that found from Grahalāghava, is in keeping with the excess of the adopted rate of precession over the calculated rate, *viz.*, 1″.4.

words, our astronomers may be said to have discovered the rate of precession correct within 1″.4 ; and it will be shown later on in the history of the attempts made by other nations to determine the ayana-motion, that our astronomers did not borrow it from others and it is really very creditable to them that they discovered it as a result of their own independent efforts. This alone would suffice to falsify* the arguments of those Europeans who charge Indians with being very backward in the work of taking observations. Even Colebrooke** says that they (Hindus) made a nearer approach to accuracy than he (Ptolemy) had done.

Findings of other Nations Regarding the Rate of Precession

The discovery of the precession of the equinoxes is due to Hipparchus, who arrived at it about the year 125 A.C. by a comparison of his own observations with those of Timocharis, made about 170 years eaelier. Its existence was afterwards established beyond doubt by Ptolemy, nearly 300 years later. Ptolemy mentions, in the seventh chapter of the Syntaxis, that having observed several bright stars in the zodiac he found that they had all increased in longitude to the extent of 2°40′ during the interval of 267 years that elapsed between Hipparchus & himself. He hence inferred that the increase of longitude amounted to 1° in 100 years which implies an annual precession of 36″, he moreover stated that Hipparchus had arrived at the same result. This was a very erroneous determination. The total increase of longitude, during 267 years, must in reality have amounted to 3° 37′, a quantity greater nearly by 1° than that assigned by Ptolemy. As the discordance seems too great to be accounted for by errors of observation, many eminent astronomers have come to the conclusion that Ptolemy made no observations at all, that in fact his catalogue of the stars is no other than the catalogue of Hipparchus reduced to the epoch of 137 A.D. by increasing all the longitudes to the extent of 2° 40′. Unfortunately there are circumstances which strongly tend to justify this serious charge. Delambre compared together the longitudes of the same stars inserted in Flamstead's*** catalogue, and supposing the interval between these two astronomers to comprehend a period of 1553 years, he hence deduced 52″.4 for the annual value of precession. This result exceeds the true value by rather more than 2″. Delambre then diminished Ptolemy's longitudes of the same stars by 2°40′ and supposing the results to be the longitudes of Hippar chus, he instituted a comparison between them and Flamstead's longitudes. Assuming the interval between Hipparchus and Flamstead to include a period of 1820 years, he now obtained 50.″12 for the resulting value of precession, a quantity agreeing almost exactly with the modern determination. (This strengthens the inference that Ptolemy himself had made no observations.)

*At several places in his notes on the translation of S.S. Prof. Whitney has simply poured ridicule on the Hindus in regard to the accuracy of their observations.

**Essays, Vol. II, p. 411.

		Birth (A.D.)	Death (A.D.)
***Flamstead :	An English Astronomer . .	1646	1719
Bradley	An English Astronomer . . .	1693	1762
Mayer	A German Astronomer . . .	1723	1762
Lalande	A French Astronomer . . .	1732	1807
Delambre	A French Astronomer . : .	1749	1822
Bessel	A German Astronomer . . .	1784	184

The efforts of modern astronomers have been constantly directed towards obtaining a more accurate value of the precession of the equinoxes. 'Tycho Brahe' fixed the annual precession at 51″ Flamstead made it 50″. Lalande by comparing the longitude of Spica Virginis as assigred by Hipparcus with its longitude deduced from observations made in 1750, obtained 50″.5 for the resulting value of precession. Delambre, by a comparision of the observations of Bradley, Mayer and Lacaille with his own obervations, was induced to fix the annual precession at 50.″1. Bessel who had studied the question very thoroughly fixed the annual value, in 1750 A.D. at 50″.21129. In 1900 A.D. the value for 365½ days will be 50.″2638.

Bessel has fully discussed the precessional motion and determined it to be 50″.21129 in 1750* A.D. The rate of precession in 1900 A.D. will be 50″.2638 in 365¼ days.

In the 11th century **A.D. Arzaei, a Spanish astronomer, declared that the rate of precession was about 1° in 75 years i.e. 50″ annually and also that the equinox oscillates east and west up to 10°. Another astrologer, by name Thabit Ben Korrah, (13th Centuty A.D.) held that the equinox oscillated within 22°, and still another astronomer of the 9th century thought that it moved through a circle of radius 4° 18′ 43″. The famous Arab astrotnomer, AL Buṭṭāni (880 A.D.), considered the equinox as oscillating at the rate of 1° in 66 years or about 55.″5*** annually. Some Arab astronomere who lived before the time of AL Buṭṭāni thought the equinox to be oscillatins 8° at the rate of 1° in 80 or 84 years (i.e. about 45″ or 43″ per year). AL Buṭṭāni's figure agrees with that of the S.S.

Accuracy of Zero-precession year

Let us see with what accuracy the years of Zero-precession have been determined by our people. The Zero-precession years according to different astronomical works are given below :—

	Śaka
Five modern siddhāntas including S.S., and Siddhānta Tattwa-viveka	421
Munjāl	449
Rāj Mṛgāṅka, Karaṇa Prakāśa, Karaṇa Kutūhala etc.	445
Karaṇa Kamala Mārtaṇḍa, Graha Lāghava etc.	444
Bhāswatī Karaṇa	450
Karaṇottama	438
Second Ārya Siddhānta	527
Parāśara's view as cited in the 2nd Ārya Siddhānta	532
Dāmodarīya Bhaṭatulya	342

*The information in this paragraph has been taken from Grant's History of Physical Astronomy, pp. 318-20.

**The information in this para has been given on the basis of Colebrooke's essay (*See* Asiatic Researches, Vol. XII, p. 209 et. seq.).

***Rehetsake observes that according to Al Buṭṭāni's opinion the equinoctial motion was 1° in 70 years (*i.e.*, 51″.4 annually). (*See* Journal of the Bombay B.R.A.S., Vol. XI, No. XXXII, Art III. Which of these two views should be taken as reliable ?

The date mentioned in the last work, Bhaṭatulya, has no independent value. The reason is this. Although the author does not mention in clear terms that the ayanāṃśa was zero in Śaka 342, the year can be derived as the initial year from his method of calculating ayanāṃśas and the reason why he adopted that Śaka year as the initial year, is that he compiled the work in Śaka 1339 and adopted 54″ as the annual rate of precession, as given by the S.S. And when Śaka 342 is adopted as the beginning year, the ayanāṃśas in Śaka 1339 come to 14°-57′. If Śaka 444 be adopted as the starting year and 60″ the annual rate, we get 14°-55′, that is, almost the same ayanāṃśa in Śaka 1339. And from this it is evident that because in his time the ayanāṃśas obtained from other works were about 14°-55′, he could not go beyond this value; and he also wanted to adopt 54″ as the annual rate; hence, his zero-precession year comes to Śaka 342. Leaving aside, for the present, the years adopted by the second Ārya siddhānta and Parāśara, let us consider other years. The Zero-precession year according to a siddhānta would be that year in which the moment of the Sun's entry into the first point of Aries, according to that siddhānta, coincides with or occurs very near to the moment of sāyana Aries Ingress. The times of mean & true Aries Ingress in Śaka 450, according to different Siddāntas, were as given below :—

	Mean Aries Ingress (Śaka 450) Caitra S. 14, Monday (20-3-528) (after mean sunrise at Ujjayini)		True* Aries Ingress (Śaka 450) Caitra S. 12, Saturday (18-3-528) (after mean sunrise at Ujjayini)	
	Ghati	Pala	Ghati	Pala
Original Sūrja Siddhānta .	45	13·5	34	49
Five modern Siddhāntas . .	46	38.2	36	14
First Ārya Siddhānta .	45	6.2	34	42
Second Arya Siddhānta . .	47	13·2	36	49
Raj Mrgaṅka. Karaṇa Kutūhala	47	24.6	37	1
Brahmagupta Siddhanta . .	52	10.8	41	47
	(On caitra S. 13, Sunday)		(On Caitra S. 11, Friday)	

The Sun's tropical longitude **at the moment of the true Aries Ingress according to different Siddhāntas was as given below :—

	Sign	Degree	Min.
Original Sūrya Siddhānta	11	29	58.9
Five modern Siddhāntas	0	0	0.3
First Ārya Siddhānta	11	29	58.8
Second Ārya Siddhānta	0	0	0.9
Rāj Mṛgāṅka etc.	0	0	1.1
Brahma Siddhānta	11	29	7.1

* The true Aries Ingress occurs 2d—10gh—15p before the mean according to S. S nd 2d—10gh—24p before mean according to Brahma Siddhānta. The difference of 2d —10gh—24p has through out been taken. It will, however, cause no difference in the result.

**The tropical longitude of the sun has been calculated from Keropant's Planetary Tables. While calculating it, 3 minutes of arc have been adopted as secular equation. In his book Keropant has taken the true Aries Ingress (Nirayaṇa) according to the Sūryā Siddhānta. But the time adopted by him for it is slightly in error. The moment of the true Aries Ingres as actually calculated from S.S. is 51 palas less than that found from Keropant's book.

This shows that Brahmagupta's Saṃkrānti differs much from the Sāyana Saṃkrānti, by about 54 Ghaṭis in Śaka 450, and the year in which both the Saṃkrāntis would coincide comes to Śaka 509 this is so because the length of the year adopted by Brahmagupta is different from that of others. The question of the length of the year has already been discussed in the course of the authors account of Brahmagupta. This point and the moments of the true Aries Ingress given above show that when the Zero-precession year was determined, it was not determined from Brahmagupta's length of the year. The Zero-precession years, that is, the years in which the moment of the true Aries Ingress of the other Siddhāntas coincided with the moment of the Sāyana Aries Ingress, on the basis of their respective year-measures are as follows :—

	Śaka
Five modern Siddhāntas including S.S.	450
Mool Sūrya Siddhānta, First Ārya Siddhānta	451
Second Ārya Siddhānta, Rājmṛgāṅka, etc.	449

This will show that, of the zero-precession years given by different works (page 215), those of Munjāl and Bhāswatī Karaṇa are very accurate. The Śaka year 444 or 445 which is now in use, is also fairly accurate.* The reason why S.S. adopted Śaka 421 as the zero-precession year, in the author's opinion, appears to be as follows :—

According to this Siddhānta, the "Ayana" completes one oscillation in 7200 years; in other words the equinox moves in one direction and returns to its place in 3600 years. It was at the initial point at the begining of Kali-yuga. The period of 3600 years from then terminates in Śaka 421 ; and the true Aries Ingress, according to S.S., occured in that year only about 29 ghaṭis earlier than the Sāyana Aries Ingress ; hence, Śaka 421 was adopted as the Zero-precession year. The work, Karaṇottama, gives 438 as the year but as the author has not seen the work he refrains from offering any comments on it ; still the year is very near to the correct one. According to the method given in the Second Ārya Siddhānta, the year comes to Śaka 527. It has already been pointed out above that as the method of finding the ayanāṃśa is similar to that of finding the declination, the rate of precession is not always the same. The second Ārya Siddhānta was written some time after Śaka 527, when the ayanāṃśas obtainable from other works, those calculated by the method of the second Ārya Siddhānta, and those found by observing the shadow, all the three amounted very nearly to the same quantity and the number of revolutions of the ayana-point was determined on that basis ; and **this is the reason why the Siddhānta gives Śaka 527 as the Zero-precession year. The same thing applies to Parāśara's view cited in the second Ārya-siddhānta. Anyway, the date of zero-precession adopted in our works is beyond doubt fairly accurate. It is the opinion of some that since the junction star of Revatī coincided with the equinox of Śaka 496. according to the accurate modern European methods of calculation, the Zero-precession year must be Śaka 496 ; but it is not justifiable . This question will be discussed later on.

* It is not claimed that the above calculation of the tropical longitude of the sun is extremely accurate. If there be a variation of 1 minute of arc, the zero precession year will also vary by a year.

** Taking this for granted, the date of the compilation of the second Āryasiddhatuā comes to about Śaka 900.

How Ayanamotion and the Date of Zero-precession were Determined

We tested the accuracy of the precessional motion and the date of Zero-precession after comparing them with the tropical longitude of the Sun found from modern European works and the rate of precession determined through accurate investigations of modern times; but we must see how our people determined these things at all. Bhāskarācārya says :—

यस्मिन् दिने सम्यक् प्राच्यां रविरुदितो दृष्टस्तद्विषुवदिनं । तस्मिन् दिने
गणितेन स्फुटो रविः कार्यः ।। तस्य रवेर्मेषादेश्च यदंतरं तेऽयनांशा ज्ञेयाः ।
एवमुत्तरगमने सति । दक्षिणे तु तस्यार्कस्य तुलादेश्चांतरमयनांशाः ।

पाताधिकार, श्लोक २ टीका.

The purport of these lines is that the difference between the calculated longitude of the Sun on the Vernal or Autumnal equinox day and the equinox concerned, is known as Ayanāṃśa. Bhāskarācārya further observes that the difference between the longitude of the Sun on summer or winter solsticial days calculated from siddhānta and allied works and 3 or 9 signs also gives the ayanāṃśa. The Ayanāṃśa should, therefore, be briefly defined as the "difference between the sāyana Sun and calculated Sun." The Sūrya Siddhānta, in the chapter on "three problems" says,

स्फुटं दृक्तुल्यतां गच्छेदयने विषुवद्वये ।। प्राक् चक्रं चलितं हीने छायार्कात् करणागते ।।.११ ।
अंतरांशैरथावृत्य पश्चाच्छेषैस्तथाधिके ।।*

त्रिप्रश्नाधिकार.

The S. S. has, in verses 17 to 19 of the above-mentioned chapter, described the method of calculating Sun's longitude from the length of the shadow and it is indisputable that the longitude so obtained must be tropical (sāyana). Hence, our works define Ayanāṃśa as the difference between the Sāyana Sun and the calculated Sun. And it is evident that by following this method some time after Śaka 445, our astronomers must have found the sun's longitude several times from the shadow and thereby determined first the ayanāṃśa for the date, then the ayana motion and from that the zero-precession year. Observation work must have been carried on for several years for this purpose. It is obvious that the longer the period of observations, the more accurate such results would be.

ASSOCIATION OF THE JUNCTION-STAR OF REVATĪ WITH AYANĀṂŚA-PROBLEM

The above discussion will also show that the junction star of Revatī (Zeta Piscium) has nothing to do with ayanāṃśa or ayana-motion. According to modern astronomy the length of the sidereal year is $365^{d}\ 15^{g}\ 22^{p}\ 53^{vp}$** 13^{vpv}. If that had been the measure of the year adopted by our astronomers, then the junction star of Revatī or some other star assumed to be the initial point of the zodiac, would have had some relation with the ayana motion. In other words, if the junction star of Revatī had been taken to be the initial pointī, then Śaka 496 would have been regarded as the zero-precession year since the equinox was conjoined with that star in Śaka 496, and ayanāṃśa would

*The meaning of this verse has been given (page 207)

**Le Vernier's Tables.

have been defined as the distance of the junction star of Revatī from the equinox. But the length of our year is not equal to that mentioned above, and hence, it cannot with certainty be called a sidereal year. Again, if the junction star of Revatī were taken as the initial point, its longitude ought to have been zero ; but S. S. and Lalla do not take its longitude to be Zero. Āryabhaṭa and Varāha have not given the longitudes of junction stars at all. Brahmagupta and almost all other later astronomers except Lalla regard its longitude as Zero ; but their initial point was not and could never have been near the junction star of Revatī. If we try to find out the year when, according to the modern S. S. the sun, at the moment of the vernal equinox, was near the junction star of Revatī, it comes to Śaka 177 ; and from that date, the position of the initial point of S. S. has been moving east of the junction star of Revatī at the rate of 8″·5 per year.* The year in which the initial point of other works except the Brahma Siddhānta coincided with Revatī and its annual rate of eastward motion, agree with those of S. S. The year in which according to Brahma Siddhānta, the sun was conjoined with the junction star of Revatī at the time of the true vernal equinox, comes to Śaka 598, and his initial point has been moving east of Revatī at the rate of 7″·38 per year. In short, if it be assumed that the year adopted by our astronomers was sidereal and that Revatī was the initial point, the year in which the equinox coincided with Revatī would be the zero-precession year, and the distance of the equinox from this star (in any subsequent year) would be the ayanāṃśa. Theoretically, the argument would be correct ; but it is not borne out by facts. In other words, we would not get the expected results because of a different length of year adopted in our works. Again, the star which is named Zeta Piscium by European astronomers and which has been determined to be the junction star of Revatī by Colebrooke and other European scholars, is a very faint star. The stars have been graded according to their importance and luminosity. Very bright stars like Spica (Citrā), Arcturus (Swatī), Aldebaran (Rohini) are classed as stars of the first magnitude ; Uttarā Anurādhā and some others are of the second magnitude, Kṛttikā & some others are of the third magnitude while Puśyā and some others are of the fourth magnitude i Revati stands between the 4th and 5th magnitude. According to some, it has even been classed as a sixth magnitude star ; there are only 2 or 3 other stars out of 27 which are similar or inferior to it in magnitude. Orhodox astronomers who can point out this star in the sky would rarely be found at present. In short it is such a faint star that there is hardly any possibility of its being used for observation. It is clear from the above (page 218) quotations from S. S. & Bhāskarācārya that it was not used for finding the ayanāṃśa, and wherever methods of taking observation have been described in our works, fixed stars have very little to do with them. The method of converting a planet's place into its sāyana equivalent and then observing it with relation to the equinox or the Sāyana sun appears to have been considerably in use. The author will now show by an example how an error would have occurred in the result, if our astronomers had assumed some relation between Revatī star and precession, that is to say, if they had adopted 50″·2 as yearly ayana motion, which was its displacement from the equinox in one year, and had defined "Ayanāṃśa as its distance from the equinox." The Sun's longitude on Friday the 23rd September 1887, Āśvina S. 7, Śaka 1809, at sunrise according to Grahalāghava, was $5^s\ 7^\circ\ 5'\ 37''$. The ayanāṃśas in this year were $22^\circ\ 45'$. Adding these to the above value, we get $5^s\ 29^\circ\ 50'\ 37''$ as the tropical longitude of the Sun. The Sun thus enters Libra (sāyana)

*The mean Sun moves by so much during the time difference between the length of the year of S. S. and the accurate modern value of the sidereal year.

after about 9 ghaṭis after sunrise and that day ought to be taken as an equinoctial day ; and the Grahalāghava almanac has given 30 ghaṭis as the length of the day on that date. For the same day, Keropant's almanac and Sāyana almanac show 30 ghaṭis as the length of the day. It, therefore, shows that the length of the day given by the Grahalāghava almanac is correct. Now, Keropant's (Patwardhanī) almanac has given 18° 18′ 13″ as the Ayanāṃśa for the date, which is equal to the distance of Revatī from the equinox. Adding this arc to the Sun's longitude as calculated from Grahalāghava, we get 5ˢ 25° 23′ 50″ as the Sun's tropical longitude. This means that the length of the day would be 30 ghaṭis, 4 or 5 days after the 7th lunar day of Āśvina Śukla, which is wrong. We must, therefore, accept the view that our astronomers were quite justified in determining ayanāṃśas on the basis of the difference between the observed longitude and the calculated longitude of the Sun, and the Ayana motion on the basis of these Ayanāṃśa figures. it would be proper to change the ayana motion, if the length of the year is changed.

WHEN WAS PRECESSIONAL MOTION FINALLY DETERMINED ?

It is rather difficult to say when the ayana motion was finally determined. The Laghumānas Karaṇa, written in Śaka 854, has given the ayanāṃśas of its time and also 60″ as the ayana motion ; and both these figures are tolerably correct. It is therefore, beyond doubt that before Śaka 800 people had completely understood the ayana motion. The astronomical works written before Śaka 427, such as the original S. S., the First Ārya Siddhānta & the Pañca Siddhāntikā do not speak of the ayana motionat all. From this it appears that the problem of ayana motion was not considered till Śaka 427. The modern S. S. does mention it and it has been fully discussed on page 206. BRAHMAGUPTA and Lalla who lived after the modern S. S. do not make any mention of the ayana motion while it has been referred to in the S. S. compiled before them. This fact makes one suspect that the verses about the ayana motion in it were interpolated later. The verses in question are given in the chapter on the three problems. As a matter of fact the numbers of the Ayana revolutions ought to have been given along with other numbers of revolutions, in the chapter on mean motions. Again, the correction on account of ayana ought to have been mentioned in the chapter on true places, particularly at the place where the methods for finding declination and 'cara' are described ; but it is not given there. There is, however, a solitary place (verse 6) in Pātādhikāra, where the correction is mentioned, in addition to the chapter on three problems, nowhere else it is mentioned. Further in the Mānādhikāra, the term " Ayana " is applied to the Sun's entry into Capricorn and Cancer. It clearly shows that these verses must have been interpolated later on, because if they are totally removed from the chapter on three problems, one would not feel any hiatres in the continuity of the text. But Bhāskarācārya seems to think that the Ayanacalana referred to by S. S. had been expanded before the time of Brahmagupta (See page 209). As Bhāskarācārya lived 500 years after the date of Brahmagupta, his statement must carry more weight than the inferences of modern students living 1200 years after Brahmagupta. One is thus at liberty to say that the problem of Ayana-Calana must have been under consideration at the time of the modern S. S. as it existed before the time of Brahmagupta. It was, beyond doubt, discussed in Viṣṇu Candra's works which existed before the time of Brahmagupta, about Śaka year 500. It was Brahmagupta's opinion that a Saṃkramaṇa was Sun's entry into a tropical sign and the sāyana " Mithunānta ", (the Sun's exit

from Gemini), the beginning of Dakṣiṇāyana. (This has already been shown in my account of Brahmagupta). Lalla's works make no reference to the ayana motion. It may be due to the fact that either it was his belief that the beginning of Dakṣiṇāyana and the end of Mithuna sign were the same, or else, the difference between the longitude of the calculated and observed (Sāyana) place of the sun was not perceptible in his time. In short, the 'ayana calana' became a problem of study about the year Śaka 500 and that a thorough knowledge of the problem was acquired by Śaka 800.

CHAPTER IV

ON OBSERVATIONS

General Description

The word 'vedha' is derived from the root 'vyadha'. Vedha is the name given to the act of observing the sun or anyother celestial body by holding a rod or a stick or some other object in between. Because the luminous celestial body is 'struck' by the rod, the act of observation has received the name "vedha". The simple casting of a look at a celestial body is termed 'avalokana' (sighting); but this act also can be termed 'observation'. Let us call this kind of observation 'dṛṣṭivedha' (i.e. look). The observation which is taken with the help of a stick or other means of taking observation, commonly known as 'instruments', should be termed 'yantra-vedha' (i.e. instrumental observation).

Our Tradition favours Observation

Europeans say that our people have no knowledge of observation, that our country lacks the tradition of taking observations, and that they have no instruments for taking them ; and they put forth this plea as the main ground for their contention that the Hindus borrowed the science of astronomy from the Greeks. Certainly it cannot at all be said that our people have no liking for observing natural phenomena or that they have no such tendency. This has been proved on the basis of many things pointed out in Part One. Thus the 27 nakṣatras, were known to us even in the dim and distant past, the Vedic times. The Rigveda refers to Saptarṣi stars and the planets. The Yajurveda describes the 27 nakṣatras at great length. In addition to this, the author has pointed out allusions to the constellations known as the pair of divine dogs, the divine boat, and the Prajāpati controlling the nakṣatras. The Taittirīya Saṃhitā narrates a lengthy story about the extreme love of the Moon for Rohiṇī, and the origin of the story is found in the phenomena of the Moon's close conjunction with the star Aldebaran, and the latter's occultation by the Moon, which occurs repeatedly in a period of six years out of every nineteen. The Āśwalāyansūtras allude to Dhruva and Arundhatī. We know of the phenomenon of saturn splitting the car of Rohiṇī 7000 years ago. The Mahābhārata abounds in the description of planets, comets and stars, and the instances have already been cited before. Even the Rāmāyana of Vālmīki refers to the planets and stars at many places. Clusters of stars are mentioned in the Yajñavalkya Smṛti. Our liking for the observation of phenomena becomes evident from these several references occurring in works which are not purely astronomical. Again, there is no doubt that some at least out of the saṃhitās compiled by Garga and others belong to a period prior to that in which our astronomical system was firmly established. They

mainly deal with the question of " grahacāra" i.e. the movements of planets through the nakṣatras. Varāha Mihıra has in a long chapter entitled Ketucāra described a good many comets. In the beginning of the chapter, he observes,'

गार्गीयं शिखिचारं पाराशरमसितदेवलकृतं च ।। अन्यांश्च बहून् दृष्ट्वा क्रियतेयमनाकुलश्चार:

which means that he was describing the comets on the basis of the descriptions given by Garga, Parāśara, Asit, Deval, and many other sages. The author is giving below some of the quotations from Parāśara and others, cited by Bhaṭotpala in his commentary on the above verse :—

पैतामहश्चलकेतु: पंचवर्षशतं प्रोष्य उदित: ।। ...... अथोद्दालक: श्वेतकेतुर्दशोत्तरं वर्षशतं प्रोष्य...... दृश्य: ।। ......शुलाग्राकारां शिखां दर्शयन् ब्राह्मनक्षत्रमुपसृत्य मनाक् ध्रुवं ब्रह्मराशिं सप्तर्षीन् संस्पृश्य ......काश्यप: श्वेतकेतु: पंचदशं वर्षशतं प्रोष्यैंद्यां पद्मकेतोश्चारांते ...... नभसस्त्रिभागमाकम्यापसव्यं निवृत्यार्धप्रदक्षिणजटाकारशिख: स यावंतो मासान् दृश्यते तावद्वर्षाणि सुभिक्षमावहति ।। ...... अथ रश्मिकेतुर्विभावसुज: प्रोष्य शतमावर्तकेतोरुदितश्चारांते कृत्तिकासु धूमशिख: ।।

पराशर.

Purport.—The Paitāmaha comet re-appears after travelling for 500 yeaıs (i.e. disappears for 500 years, after it is first seen and then appears againt. The comet named Uddālaka Śvetaketu appears after travelling for 110 years. The comet Kāśyapaśvetaketu whose tail is pointed like a spear, and who, after the disappearance of the comet Padmāketu, first appears in the East, after having travelled for 1500 years, and who, after contacting the Brahma (Abhijit) constellation, the Pole star, the Brahmarāśi* and the Great Bear, traverses the third part of the sky, turns to the left and gives plenty of crops for as many years as the number of months it remains visible in the sky, with its semi-circular tuft of hair. Vibhāvasujaraśmiketu, after having travelled for 100 years, makes its appearance near the Kṛttikā stars after the Āvartaketu. It has a tail of smoke.

Descriptions of many such comets are available. The comets may have received the names Uddālaka, Kāśyapa etc. after the Ṛṣis who discovered and investigated the nature of these comets. This is just like what we find at present in the case of comets such as Enkī's comet, Halley's comet, etc. named after European astronomers ; and these descriptions appear to have been given on the basis of researches traditionally carried on through centuries. The statements of Āryabhaṭa and Brahmagupta that they determined the positions of the Sun and Moon after observing the eclipses have already been given. If the work of taking observations is carried on continuously for several years, it gives useful results ; and it is not possible to do this without royal patronage. Varāhamihira has described how astronomers deserve respect. He has also written that kings should employ astronomers in their service, that some of them should be engaged in the task of taking daily observations of the sky, and that they should distribute amongst themselves different parts of the sky, and then take observations. From this and

* The word Brahmarāśi occurs in Chapter III of Bhīṣmaparva in Bhārata, as can be seen from the extract given in Part I (page 117). It seems from this and also from the above reference; as also from the fact that Brahma was the deity controlling the Abhijit nakṣatra, Brahmarāśi was the name given to cluster of stars around the Abhijit star and the description of the place occupied by the comet agrees with what one may find on the celestial globe. There is nothing impossible in this ; particularly the semicircular shape of the hair (described in the passage) tallies exactly with the position with respect to stars in the sky.

from the astronomical works, Rājamṛgāṅka Karaṇa by King Bhoja, and Karaṇa Kamala Mārtaṇḍa by King Daśabala of Vallabha dynasty which have been mentioned before and from the fact that several authors of astronomical works had the patronage of kings, as can be seen from their own account, it appears that the work of taking observations used to be carried on by royal support. Corrections recommended by different astronomers to be applied to the mean places of planets have been given before at several places. It is evident that these could not have been devised at random. Keśava, for one has described the observations actually taken by him (page 129). KAMALĀKARA the author of Siddhāntatattvaviveka has declared that the pole star has a shifting motion. Even in these days we come across persons who have a liking for observing things. One finds several persons who can correctly point out the planets and several stars even though they have not studied astronomy. Thus two persons who had absolutetly no knowledge of English, Sanskrit and astronomy once casually told that the pole star is not stationary ; and one of them was very fond of observing stars, risings and settings of planets and their conjunctions, and he was very helpful to the author. Once a Vaidic Brāhmaṇa named Pādhye, a resident of Āgāśi, casually met the author in Poona in Śaka 1809. He had not studied any system of astronomy. Still, he chanced to state that, while most of the stars moved from east to west, some stars (those near the North Pole) move in a reverse direction, that is from west to east ; and he told that he came to know of it from his brother Nārayaṇā Janārdan Pādhye. That brother died in Śaka 1795. At that time he was about 22 years old. He was surprisingly intelligent. There may be several such people living. The experiences related here may appear very trivial to some ; but man must have acquired knowledge of astronomy in the initial stages, through the efforts of such persons ; and my object in relating such experiences is to show that the habit still persists among our people. Europeans are surprised to see that while the Saura, Ārya and Brahma siddhāntas mention the numbers of revolutions and other elements of planets, no hint is anywhere given as to how these were calculated and no information of the observations taken has been recorded in them. But they do not take into considaration the conditions in ancient times and the beliefs of our people. In those times when even scripts or any means of writing, not to speak of the printing presses, were not easily available or were even non-existent and all knowledge was preserved by the tradition of being vocally imparted by the teacher to his disciples. Hence, it was but natural that only the siddhāntas which embodied the results of research survived while their sources perished. Again, nobody will now feel astonished if one predicts the time of the occurrence of an eclipse. But in ancient times a man who could predict these phenomena was naturally considered to be superhuman. If he compiled a work, he would naturally incorporate in it only the resulting principles without mentioning their preliminary forms or the means employed in arriving at them. Then in course of time, the work would possibly come to be regarded as 'apauruṣeya' (divine) after the author's name is forgotten & lost ; and once this practice secured a firm footing, the future authors of 'human' works abstained from mentioning the preliminaries leading up to the final results. These were quite probably the reasons why our ancient works lack the information about the observations taken, similar to what we find recorded in Ptolemy's works about his own observations and those taken by Hipparchus, or in the works of later western astronomers. However, some information about the individual efforts made in respect of observations has already been given and some more will be given further on.

DESCRIPTION OF INSTRUMENTS

The instruments for locating the positions of planets and those for measuring time will now be described. The works compiled by Bhāskarācārya are widely known. Hence, it will be of convenient first* to describe the instruments mentioned by him and then to give a brief account of what we find in other works.

GOLA YANTRA
OR
(Armillary Sphere)

A straight round stick of uniform thickness should be taken. It may be called "pole-stick" (dhruva-yaṣṭi). A small spherical ball which can easily slide should be fixed in it, in the centre, to represent the earth, Then a (concentric) sphere to represent the starry sphere should be fixed all round it, It should represent the celestial sphere in which the Sun and other planets are seen to move round the earth. The construction of the starry sphere (bhagol) is as follows :—

Prepare an exactly circular ring**. It should be so tied at two points to the pole stick that it will be divided by those points into two exact parts. A second ring of the same size should be tied to the stick, so that it will cut the stick in those two points, will be perpendicular to (the plane of) the first ring, and will itself be bisected at the two points. These circular rings are called the pair of "standard great circles". Tie a third ring to these rings at four points so that it will be at right angles to them both, and the pole stick will be its axis. This ring is termed '*Nāḍīvalaya or Viṣuvavṛtta*'. Divide this ring into 60 equal parts to represent nādīs (or ghaṭikās). A circular ring of equal circumference, called 'Krāntivṛtta' or the ecliptic circle should be tied to the '*equator-circle*' cutting it at two points and inclined to it at an angle of 24°. The Sun moves in this circle. It should be divided into 12 equal parts to represent the signs. If the ball representing the earth be supposed to be a *planet* other than the sun, 'great' circular rings should be tied to the 'ecliptic-circle' at angles equal to the inclinations of the orbital planes of the planets. These also should be marked to show the signs. Then circular rings showing diurnal circles should be tied to the ecliptic circle. While tying the circular rings, care should be taken to see that a portion of the stick is kept projecting and these ends should be passed into two tubes fixed in the celestial sphere whose construction is described later on. The ends of the polestick should point to the poles of the equator, so that the north end of the stick should be found to make an angle, equal to the latitude of the place, with the

* This description has been given from the chapters on Golabandha and Yantras (instruments). If an attempt be made to describe in detail the instruments along with an explanation of their names, such as Nāḍ valaya, and other terms, much space will be occupied, and even with all that, it is very difficult to present a description that would enable one to understand them properly without actually seeing them. Hence, only a brief description has been attempted. These however. will help even a layman to understand well the chapters on Golādhyāya and Yantrādhyāya by Bhāskarācārya. If all these instruments are made in the Chhatre memorial scheme, they will prove very useful at a moderate cost.

**Straight, pliable, and soft bamboos have been recommended for preparing these rings. Even those made out of wire will do. These rings themselves represent circumferences of circles.

north pole of the equator lying in the celestial globe which is fixed clearly all round the 'starry sphere'; and the ends of the pole stick should be so passed into tubes that, while the 'khagol' (celestial sphere) would be kept fixed in position, the starry globe would freely rotate in it. The celestial globe should be so set as to envelope the starry globe. Its construction is as follows. Its circular rings should, of course, be larger in size than those of the starry globe. The ring representing the 'samavṛtta' (prime vertical) which passes through the zenith, nāḍir, and the east and west points, similarly the ring representing the meridian, as also the two other rings representing the secondary directions—all these four rings should be of the same circumference. These should be tied to one another, so that each of them would pass above and below the others. The ring representing the plane of the horizon should be tied to them all, midway between them. The north pole should be set above the horizon at an altitude equal to that of the latitude and the south pole at an equal depression below it. Prepare a ring representing the ' Unmaṇḍal' (six o'clock circle) i.e. the great circle which would pass through the east-west points and both the poles which are points in the meridian circle to which the ends of the pole stick in the starry globe are directed. Then tie a 'nāḍivalaya' (celestial-equator-circle) which lies in the plane of the equator of the starry globe and which is larger in size. This should be graduated into ghaṭis. Then fixing nails at the points representing zenith and nādir, another ring should be so fixed in position that it would be free to rotate in a vertical plane with the two nails as the pivots. This is to be called a 'dṛngmaṇḍal' (i.e. the vertical circle for observation). As this is to be rotated inside the celestial glove it should be somewhat smaller in size. A planet is to be observed after so rotating the vertical circle that the planet would be seen in the plane of the observation circle. This celestial globe should be so fitted around the 'starry globe' that the ends of the pole stick could be made to pass through the two tubes fitted on to it. Then after fixing two tubes in the 'khagol' from the outside, another globe called driggola should be fitted on ; and all circular rings like those in the 'khagol' and 'bhagol' should be fixed on to it. This globe is to be constiructed so as to enable one to have a proper understanding of the arcual lines like 'agra' (amplitude) 'kujya' (the radius of the earth) etc., which require the reference to two globes. The whole structure is now Called a 'gola' (i e. a globe). (Our astronomers sometimes used the term "kṣetra", to denote lines.)

The orbits of planets should, if necessary be tied in this globe separately with circles of aphelia and perihelia. This globe has been described to show the construction of the Universe. In fact it is very difficult to tie together all these rings, and it is still more difficult to take observations with their help. for instance, if the starry globe is fixed inside a 'khagola', it will be difficult to fix the observation circle. It cannot be believed that Bhāskarācārya and others could not realize these difficulties. It is clear that at the time of taking actual observations only the most necessary rings should be made use of, and observation can thus be taken. We had no instrument of the type of astrolabe designed by *Hipparchus ;* but this speaks for the independence of our works in this respect. The above globe can be used in place of the astrolabe, *Brahmagupta*, *Lalla*, and both the Āryabhaṭas have recommended the construction of the same kind of globe. The globe described by the First Āryabhaṭa is less complicated than this.

Bhāskarācārya has mainly described nine kinds of instruments, and their chief use is to find time ; but three of them can be used mainly for taking observations of the celestial bodies. I shall here describe all of them briefly.

1. *The Cakra Yantra* (The disc instrument):—

Procure a disc* of metal or wood. Make a fine hole at its centre. Provide some pivot to the rim of the disc, to which a chain etc. can be attached to support the instrument with. Mark on the disc a line passing through the pivot and the central hole : (this will always remain vertical when the instrument is held suspended in position). Mark on it another line perpendicular to the first line and passing through the centre. Mark graduation lines on the circumference of the disc to indicate degrees. Pass a rod through the hole, perpendicular to the disc. It will serve as an axis. Hold (in hanging position) the disc, with the help of the support before the Sun in a vertical plane, so that the axis will cast a shadow on the disc. The degrees counted from the point in which the shadow cuts the rim to the point in which the horizontal line cuts it, will give the altitude of the sun, and the degrees counted from the point to the lowermost point of the disc, will give the zenith distance. (The time of the day can be calculated from this). The same disc may be so held that any two of the 'zero-latitude' stars, Puṣya, Maghā, Śatatārakā and Revatī will be found to be in the plane of the rim. (The disc will thus be held in the plane of the ecliptic). Then the planet will be sighted by moving the eye to and fro, so that the axis would intercept the sight ; the longitude and latitude of planets can thus be found. It is in a way similar to the 'dṛṅmaṇḍal' of the Gola Yantra.

2. *The Cāpa* (Semi circular disc) :—

The half part of the Disc instrument is called a 'Cāpa' instrument.

3. *Turyagola* (Turiya Yantra) :—Half part of the 'Cāpa' instrument *i.e* a 'quadrant' forms a Turiya instrument.

These three instruments are chiefly used in taking observations.

4. The *Gola* instrument (Globe instrument) :—Placing a 'bhagola' in a 'khagola', mark a spot on the ecliptic ring at a place where the sun is expected to be on a particular day. Then so rotate the 'bhagola' that the mark will cut the horizontal circle. Mark that point in the horizon in which the plane of the equator in the 'bhagola' will appear to cut. Then again rotate the 'bhagola' so that the spot marking the Sun's position will cast a shadow on the 'bhugola' *i.e.*, the terrestrial globe. Where the shadow is cast, the number of ghaṭis indicated between the spot and the 'nāḍivalaya' will give the number of ghaṭis elapsed after sunrise on that day. Then the point of the ecliptic in contact with the horizon will give the ascendant at the moment.

5. *The Nāḍivalaya* :—Procure a circular disc. Graduate its rim in ghaṭikās. Pass a rod through its centre perpendicular to the disc. When the rod is held, pointed to the pole, it will cast a shadow on the rim ; and from it the hour angle (natakāl) or its complement can be read. If this very disc is so fitted in a globe that the pole stick will pass through its centre and the terrestrial globe will occupy the central position in it, and if marks indicating ghaṭikās, rising of signs, and the sixfold division of signs (lagna ; horā ; dreṣkāṇa ; navāṃśa ; dwādaśāṃśa & triṃśāṃśa) are made on it, then the shadow cast by the stick will help in finding the time elapsed and the sixfold divisions.

6. *The Ghaṭikā* Instrument :—This is too well known.

7. *The* Śaṅku (Gnomon) :—

Śaṅku is a piece of a round, straight and uniformly thick rod 12 'anguls' in length and having its ends plane and uniform. The chapter on three problems describes methods of finding time etc. from the shadow cast by it.

*The description will show that it is not a wheel but a disc cut out from a sheet (of metal).

8. *The Phalak* Instrument :—It is an instrument for finding time designed by Bhāskarācārya on the principles of the Cakra Yantra. Its details are not given here for want of space.

9. *Yaṣṭi Yantra* (Pole instrument) :—

Draw a circle with any radius on an even horizontal ground. Mark off principal directions on it and then draw arcs showing 'agrā' (amplitude of the day), both in the East and the West. Draw another concentric circle smaller in size and having a radius equal to "dyujyā " (sky-radius). Mark off points on it to show 60 ghaṭis. Take a stick equal in length to the radius of the outer-circle and hold it pointing to the Sun, with its one end placed at the centre of the circle, so that the stick will cast no shadow. Place in the smaller circle a rod which is equal in length to the distance of the other end of the stick and the end of the amplitude marked in the east. The arc showing ghaṭis intercepted between the ends of the stick will show the time elapsed (in ghaṭis). If the sun is in the West, the distance between the ends will give the number of ghaṭis showing the time left for the day to end. The methods of finding a number of things like 'palabhā', with the help of the 'Yaṣṭiyantra' have been described. Brahmagupta and Lalla have described the method of finding the distance between the Sun and the Moon, and from that the tithi, with the help of a similar but somewhat different type of a 'yaṣṭiyantra'.

Bhāskarācārya has mentioned two other additional self propelled instruments for finding time.

We find in Atharva Jyotiṣa, discussion of the shadow cast by a gnomon, which proves* that the gnomon was known to us before our science of astronomy came in contact with that of the Westerners. The Pañca Siddhāntikā contains a chapter on instruments, which is not quite intelligible ; still it appears that many of the instruments described by Brahmagupta and others were in use in those times. Āryabhaṭa I has not described any instruments at all, but has mentioned a globe as described above. He has, in addition, stated that a globe should be so prepared for finding time that it will automatically rotate with the help of mercury, oil, or water.** Take a wheel. Fix in it somewhat hollow spokes half filled with mercury, with their ends sealed. The wheel will then rotate automatically. Brahmagupta and Bhāskarācārya have mentioned one such automatic instrument. From the globe instrument of Āryabhaṭa described above and from the references in the Pañca Siddhāntikā to some wonders occurring automatically by means of the instruments, it appears that at the time of Varāhamihira there existed such instruments and some other kinds of 'swayaṃ waha' *i.e.*, automatically working instruments. Varāhamihira and Āryabhaṭa have not described the process of construction. Brahmagupta also has described, in addition to the above instruments, some other wonders happening automatically, but has not described their processes.

Instruments of the same type or with certain variations as those described by *Bhāskarācārya* are met with in the works of *Brahmagupta* and *Lalla*. ***But both of them have mentioned some additional instruments for finding time,

---

*"(3) Atharva Jyotiṣa ",

**Āryabhaṭya, Golapīda, coāuplet No. 22.

***Bhāskarācārya invented a new instrument called the Phalak instrument ; but its origin is to be found in the Cakrayantra itself. Out of the remaining eight, Brahmagupta has not explicitly mentioned the Gola & Nāḍivalaya as seperate instruments. He has, however, mentioned the Golabandha which includes the two. Lalla has not mentioned the Nāḍivalaya out of the eight instruments, but it is included in the Gola itself. It is, however, somewhat surprising that he has not mentioned the Turiya instrument.

viz. Kartarī, Kapāla and Pīṭha. The modern S. S. does not describe any instruments in detail ; still it has mentioned the names of the following instru. ments :—Swayaṃ-waha, Gola, Śaṅku, Yaṣṭi, Dhanu, Cakra and Kapāla. It is interesting to note that the Pañca Siddhāntikā, Āryabhaṭīya, modern S.S. and Lalla-tantra do not anywhere mention the 'Turiya yantra'.* It was Ptolemy among western astronomers who first invented the quadrant instrument. Before his time, they used the complete circular instrument for taking observations ; but later on, the Western astronomers began to use the quadrant instrument for all purposes. In modern times, however, the quadrant instrument has completely disappeared and the complete circle instruments have come into use in their place. Modern scholars accuse Ptolemy of having taken a retrograde step by introducing the quadrant instrument.** The purpose of mentioning this here is that while the quadrant instrument has been mentioned by Ptolemy, it was not known to our astronomers till śaka 500. It, therefore, proves that the Romaka Siddhānta is neither a translation of Ptolemy's work nor has it been compiled on the basis of that work and that we knew nothing about Ptolemy's work, till at least Śaka 500. The same thing was seen before from our study of the Romaka Siddhānta (Page 12). One more important thing which comes to our notice is that all our instruments have been invented by our astronomers quite independently ; and the quadrant instrument which came into use later on, was also independently invented. It could have been easily suggested by the '*cakra*' and cāpa instruments ; and since it occurs for the first time in Brahmagupta's work, it must have been invented by him.***

The second Āryasiddhānta and modern siddhāntas by Romaśa, śākalya, Brahma, and Soma do not contain the chapter on instruments at all.****

ANCIENT OBSERVATIONS OF WESTERNERS

It would not be irrelevant to say something here about the ancient methods of observations of the Westerners.† The Chaldeans, to whom the origin of astronomy is usually ascribed by European scholars, do not seem to have attained any excellence in this important department of the science. Their observations of eclipses of the moon, as cited by *Ptolemy*†† are as rude as can possibly be imagined. The time is expressed only in hours, and the quantity eclipsed in terms of the half & quarter of the moon's diameter. *Herodotus* states that the Greeks were indebted to the Babylonians for the *pole*, the *gnomon* and the division of the day into twelve hours. The pole seems to have been

*After detecting this omission, the author could not find time for reading the texts of these works minutely, particularly with an eye to the word "turiya". I have, however, gone through all those portions of the works where that word could possibly have occurred and ascertained that it does not occur there.

**Grant's *History of Physical Astronomy*, p. 440.

***The fact that no mention of the 'turiya' instrument has been made in the Sūrya Siddhānta is an additional proof to show that the work was compiled before Brahmagupta's siddhānta.

**** That does not, however, prove that these Siddhāntas were compiled earlier than the Sūrya and other siddhāntas.

†This paragraph has been written on the basis of Grant's *History of Physical Astronomy*, Chapter XVIII.

††Rehatsaik states that the most ancient of these observations are the three eclipses which occurred in the years 719 and 720 B.C. (Jour. B.B.R.A.S. Vol. XI).

a concave hemispherical sun-dial, having a vertical style in the centre, by means of which the interval included between sunrise & sunset was divided into twelve equal parts. It is probable that by the use of the gnomon the Chaldeans succeeded in obtaining an approximation to the length of the solar year, but there is not the smallest reason to suppose that they employed it in determining any other of the fundamental facts of astronomy. Indeed, they do not seem to have made observations at all for the purpose of forming materials to serve as the groundwork of future reasoning. They simply contented themselves with noting the more remarkable phenomena as they occurred, and hence deducing a few rough conclusions of a general nature. It would appear, however, that by comparing together the Chaldean records of eclipses some of the Greek mathematicians ascertained with considerable accuracy several periods relating to the motion of the moon. The earliest astronomical observation recorded as having been made by the Greeks previous to the establishment of the *Alexandrian school*, is a determination of the summer solstice by Meton, in the year 430 A.C. The instrument, termed a heliometer, which was used by *Meton* on this occasion was, in all probability, no other than a modification of the gnomon. The date of this solstice has been chosen for the epoch of the Metonic cycle of nineteen years.* A new era commenced in the history of astronomical observation when *Alexandria* became the capital of the civilized world. Under the liberal patronage of the Ptolemies a magnificent building was erected, in which were deposited circular instruments for determining the positions of the heavenly bodies, and every facility was given to astronomers for prosecuting a continuous series of observations. Timocharis and Aristillus are the earliest individuals mentioned in connexion with this school. These astronomers appear to have flourished about the year 300 A.C. *Ptolemy* (150 A.D.) cites several of their observations. Among these are the declinations of a few of the principal stars and the records of eclipses. It does not appear that they were acquainted with any method for determining the right ascensions of the stars. Eratosthenes (275 B.C. circa) one of the Alexandrian astronomers, determined the obliquity of the ecliptic to be 23° 51′ 19″. It is manifest that neither the distances of the stars from the equator nor the obliquity of the ecliptic could have been determined even roughly without the use of instruments. In treating of the obliquity of the ecliptic, Ptolemy describes an instrument for determining the meridional altitude of the sun. It was composed of two concentric circles, placed exactly in the plane of the meridian, one of which revolved within the other about their common centre. The inner circle carried two small prisms attached to the opposite extremities of a diameter, and when the sun was on the meridian, it was turned round until the shadow of the upper prism fell exactly upon the lower one. An index, affixed to the latter, then marked upon the graduated limb of the outer circle the meridional altitude of the Sun. It was, in all probability, by means of an instrument of this construction that Eratosthenes determined the altitude of the Sun at each of the solstices & hence deduced the obliquity of the ecliptic. Ptolemy cites a passage from Hipparchus which shows that at Alexandria they used to ascertain the passage of the Sun through the equinox by means of a circular ring of metal disposed in the plane of the equator—the shadow of the upper half being watched until it fell upon the inner or concave surface of the lower half. It is not by what means the earlier astronomers

*Meton fixed 6940 as the number of days in a cycle of 19 solar years (Indian Eras by Cunningham, page 43). This makes the length of the year 365d 15gh 47 368p 31. Calippus made an improvement in the Metonic cycle by discovering the cycle of 76 years by which the length of the year became exactly 365d—15gh (Indian Eras, p. 43). It is worth noting that none of our astronomical works have adopted these cycles or lengths of year.

determined the declinations of stars. Whatever credit may be due to the earlier astronomers of the Alexandrian school for the sound principles of observation which they appear to have practised, it is to Hipparchus alone that the establishment of astronomy, as a science of calculation based upon observed facts, is to be attributed. He determined the length of the year to be—365d—14g—48p as against the former measure of 365d—15g.

He invented the astrolabe with which he used to find the longitudes and latitudes of celestial bodies. No one before him had a correct knowledge of the sun's apparent motion; and it was he who first compiled tables for calculating sun's true place; these were not known to anyone before him. He recorded observations of the moon, and appears to have compiled tables for finding the true place of the moon. He recorded observations of planets also. The observations recorded by Hipparchus proved useful to Ptolemy in deducing the correction for moon's longitude, called "evection" and to establish the rule for finding the planetary motions. It has already been stated that Hipparchus found the longitudes and latitudes of stars. Ptolemy was not skilled in the work of taking observations. He invented the quadrant instrument. It is nowhere mentioned in clear terms how all these astronomers used to find time. It appears that they used to measure time by the shadow instrument and the clepsydra ('ghaṭi' instrument). Sometimes they used to record what part of the ecliptic was transiting the meridian at the time of taking observations. The Arabs did not bring about any appreciable improvement in the instruments of observation; however, their instruments of observation used to be larger and better than those of the Greeks. The astrolabe used by them was much more complicated.

The above account will show that none of the various lengths of the yeas described so far agrees with those established by our siddhāntas. It hal been proved in the study of the five ancient siddhāntas, that though the origina Romakasiddhānta may have been compiled on the basis of the work of Hipparchus, the Romaka was not the most ancient of our works and that there were works on mathematical astronomy even before the Romaka (page 2).—

Now the author will describe our independent works relating to instruments and observatories :—

SARVATOBHADRA YANTRA :—It appears from two verses quoted by Bhāskarācārya, as from this work, in the chapter on instruments in the Siddhānta Śiromaṇi, that he wrote a work of this name for describing instruments, but as the work is not available, it cannot be described how the instrument was constructed.

YANTRA RĀJA :—There lived in Bhṛgupura an astronomer Madan Sūri by name. His disciple Mahendra Sūri compiled this work in Śaka 1292. There is at the beginning of the work a salutation to 'sarvajña' (i.e. the Knower of all things). From this it appears that this writer must have been a Jain. The work consists of five chapters viz. Gaṇita (mathematics), Yantraghaṭanā (principles of instrument making), Yantra racanā (construction of instruments), Yantrasādhanām (use of instrument), Yantra vicāraṇā (theory of instruments), and has in all 182 verses in it. MALAYENDU SŪRI has written a commentary on it, in which he says that Mahendra Sūri was the Head Astronomer at the Royal Court of Emperor FEROZE SHAH. The Samvat 1435 (Śaka 1300) has been adopted in many of the solved examples. In one case the Samvat 1427

has been taken and in another, Samvat 1447 ; and the commentator calls *Mahendra Sūri* his preceptor, This shows that he (Malayendu Sūri) was his direct disciple ; and the date of compilation of the commentary also was about Śaka 1300. Sudhākara Dwivedī published this work at Vārānasī. The author observes in the very first chapter,

क्लप्तास्तथा बहुविधा यवनैः स्ववाण्यां यंत्रागमा निजनिजप्रतिभाविशेषात् ॥
तान् वारिधीनिव विलोक्य मया सुधावत् तत्सारभूतमखिलं प्रणिगद्यतेत्र ॥

अध्याय १

" The writer is presenting in this work the description of instruments which he has gleaned from various works on instruments written by Yavanas, just as nectar is taken out from ocean."

He has assumed 3600 as the radius and 23° 35′ as the maximum declination; he has given tables of sines, declinations and sky diameters for each degree and has given the length of the shadow cast by a gnomon of seven inches for each degree of altitude, varying from 0° to 90°. The commentator has given the latitudes of about 75 cities. The author of the work has given sāyana longitudes and latitudes of 32 stars which are useful for observation, and has mentioned 54″ per year as the precessional motion. It is not possible to describe the construction of the instrument, Yantra Rāja, briefly, and hence it is not given here. With the help of this instrument the following things can be found directly from observation :—the altitude, zenith distance, longitude and latitude of the Sun ; planets and stars ; distance in degrees between any two celestial bodies, the latitude of a place, the ascending sign and the time and length of the day. There is a commentary on this work written by Yajñeśwara in Śaka 1764.

DHRUVA-BHRAMA-YANTRA :—PADMANĀBHA, son of Nārmada compiled this work. It has already been pointed out (page 126) that the date of this Padmanābha is about Śaka 1320. The work consists of 31 verses and has a commentary written by the author himself. This instrument known as Dhruvabhrama Yantra is meant to find time and it consists of a rectangular plank of wood, the length of which is double the width, and which has a chink bored in it parallel to the shorter edge; the constellation of Dhruva-matsya (polar fish) is to be observed through the chink. The author does not intend to describe here in detail the construction of the instrument meant for finding time. The author has described the " Polar fish "* in the following words :— " There is a cluster of 12 stars round the North Pole. It is called the ' polar fish '. It has two bright stars, one of which is regarded as its mouth and the other as its tail. One of these is on one side of the pole at a distance of 3° and the other lies at a distance of 13° on the other side." The author has described the construction of an instrument by which time can be noted at night by observing the stars situated at the mouth and the tail. A method has been described for finding time by observing other stars at night and even the Sun during the day. Similarly, even the ascendant at any moment is found with the help of this instrument, and it evidently gives the sāyana ascendant. The mean altitudes of junction stars of 28 asterisms at transit as observed in latitude 24° N have been mentioned. It shows that the author may have been the resident of a place whose latitude is 24°.

*See commentary on the 11th verse.

YANTRA CINTĀMAṆI

A mathematician named *Cakradhara*, son of Vāmana, compiled this work and it has a commentary written by the author himself. In addition to this, there is a commentary on the work by Rāma, son of Madhusūdana, a resident of *Pārthapura*. The author has not given his date, but as he has quoted in his commentary some lines from Bhāskarācārya's Siddhānta Śiromaṇi, and Rāma, the commentator, has mentioned Śaka 1547 as the date of his commentary, the work must have been written some time between Śaka 1100 and 1500. His words, " kṣitipālamaulivilasadratna grahajñyāgraṇī cakradharaḥ " meaning " Cakradhara, the leading astronomer, and who is a jewel in the crown of kings " shows that he had the patronage of some king. The work has four chapters containing 26 verses in all. *Dinakara*, son of Ananta belonging to Śāṇḍilya gotra wrote a commentary on it with examples in the Śaka year 1767. Yantracintāmaṇi is a kind of quadrant instrument. The observations taken with this instrument give the longitudes of the Sun and the Moon, and also the longitudes and latitudes of five planets, the desired time, and the ascendant true for that momemt, and such other things. The planetary positions and the ascendant are sāyana.

PRATODA YANTRA

Gaṇeśā Daivajña, the author of the *Grahalāghava*, compiled this work on instruments. It contains 13 chapters. The author claims that even while riding a horse one can find time by observation with the help of this Pratoda yantra, and also the shadow cast by the gnomon at that time. Its construction is not described here for want of space. Sakhārāma and Gopinātha have written commentaries on this work.

GOLĀNANDA

This instrument was invented by Cintāmaṇi Dikṣit (page 174). He has written a work entitled *Golānanda* concerning the instrument. It contains 124 verses. It has chapters (*adhikārs*) on the construction of the instrument, mean places, true places, three problems, eclipses, shadow, risings and settings of planets, observations and conjunctions. The following things can be found from observations taken by the Golānanda instrument :— Equation of centre to be applied to planets, planet's distance from the earth, true motion, declinations, ascensional difference, ascendant, directions, amplitude, zenith distance, *valan* (deflections), parallax, *nati* (parallex in latitude), latitude, *dṛkkarma* and the desired time. There is a commentary on the work entitled *Golānandānubhāvikā* by Yajñeśwara.

There may be several such works on instruments. Rāma, the commentator of Yantra Cintāmaṇi, observes :—

विलोकितानि यंत्राणि कृतानि बहुधा बुधैः ॥ मतः शिरोमणिस्तेषां यंत्रचिंतामणिर्मम ॥

" I have seen almost all instruments prepared by learned men, and it is my belief that this ' yantracintāmaṇi ' is the best of all." This shows that several kinds of instruments were in use.

The instruments described in Siddhāntaśiromaṇi and other independent instruments mentioned above are rarely seen constructed by any one at present. The gnomon and the quadrant instrument are found at some places. Some instrument by which the time of the day can be found is seen at a number of places.*

OBSERVATORIES

Let us now consider the question ofobservatories. It is evident that if the instruments of observation are permanently fixed they will be found more useful for observation. A building is specially erected for this purpose, and instruments are fixed in it and the work of taking observations is carried on there. Such a place is called '*Vedhaśālā*' (or Observatory). It seems probable that in ancient times in our country such places might have been built under royal patronage and reserved for this purpose ; but we do not anywhere find their description. In some places, stone slabs are found on which lines showing directions are marked. It has been mentioned before, that Cintāmaṇi Dikṣit had such an arrangement for showing directions made at his place of residence in Sātārā. In 1884, the author had gone to Indore for taking part in the Sāyana pañcāṅga controversy. There he learnt that a place had been purposely set apart in the palace area, where lines showing directions have been marked, and astronomers, engaged by the Mahārājā Tukoji Rao, sometimes used to take observations there. The author met an astronomer from Bid who told him that some years ago some instruments had been constructed for the purpose of carrying on the work of taking continuous observations with the help of a party of astronomers maintained by the Moghul Government at Hyderabad ; but the work was later on discontinued. The author has seen astronomers at times taking observations by means of tube instruments. Such attempts on a moderate scale must have always been made in the past, but we have at present a reliable information about only one attempt of this kind made on a very big scale. It is as follows :—Jaya Siṁha (page 169) built five observatories. The author is giving below, an extract** from the introduction to his own works

---

*While this chapter was being printed (during the months of Vaiśākha and Jyeṣṭha of Śaka 1818) Mr. Naraso Gaṇeśa Bhānu, a resident of Mirāj, sent to the author some papers on which he had copied out diagrams of some of the instruments. Bhānu is not an astronomer. He is at present a pensioner of the Mirāj State, still, he has a great liking for this subject. The original instruments of which these were the copies were constructed by one Sakhārāma Jośī, a resident of Koḍolī near Kolhapur, between Śaka 1712 and 1718. Of these, some were probably made of cast brass, as stated by Bhānu. They include *grades of some* instruments and 'turya yantra', 'phalak yantra' 'dhruvabhramana yantra' and other instruments. One kind of Yantrarāj instrument was constructed at Saptarṣi (Sātārā) in Śaka 1712 ; it has marked on its dial 17° 42′ as the latitude of Sātārā, and the altitudes of junction stars of 27 asterisms and of some other stars at the times of transit, along with their directions ; e.g. the altitude of Maghā has been given as 83° 57′ South. Another Yantrarāj has been constructed for Karavīr (or Koḍolī) in Śaka 1718. It has marked on it 17° 21′ as the latitude of Karavīr (Koḍolī) and the altitude of Maghā as 84° 15′ South. According to modern astronomy, the latitude of Sātārā is 17° 41′ and that of Kolhapur 16° 41′, and in Śaka 1718, the declination of the junction star of Maghā was about 12° North ; and the transit altitudes of the star were 84° 19′ at Sātārā and 85° 19′ at Kolhapur. Anyway, Sakhārāma Jośī appears to have been very painstaking. The above-mentioned instruments are at present with his great grandson Sakhārāma Śāstrī at Kadeguddi near Belgaum in the Śāhāpur Taluka. His another great grandson Moraśāstrī lives at Miraj, and he has also some instruments with him.

**This extract has been taken from an article by the well known scholar, William Hunter, published in Asiatic Researches, Vol. V, pp. 177-211.

KSIZ MOHOMED by name. It will give a complete idia about his efforts :— "so incapable are human beings of comprehending the powers of the Almighty that Hipparchus can be said to be simply a rustic, and Ptolemy only a swallow. The theorems of Euclid are but an imperfect form of divine work. Similar by, thousands of people like Jamsedkasī and Nasīrtuśī, have laboured in vain and became fatigued. The calculations made from works on astronomy like those of Sayad Gurganī and Khayānī, the Ākbarśāhī work of Inśil-al-Muḷācand and astronomical works of Hindu writers as also those of European writers, do not agree with observed phenomena ; especially, the new moon's appearance, risings and settings of planets, eclipses and conjunctions of planets do not agree with observation at all. When this fact was told to Emperor Mohomadśāhā†, he asked him (*i.e.* Jaya Siṃha) to decide the matter. He erected at Delhi instruments like those erected by Mirzā Ulugbeg at Samarkaṇd................Jaya Siṃha found that his ideas about the correctness of results could not be realized by brass instruments, because the instruments were small, not convenient for showing minutes of arc, their axes shift their places and get worn out ; the centres of circular plates also shift their places and the planes of instruments get twisted. He thought these to be the reasons why the calculations of Hipparchus and Ptolemy did not tally with observed results. He, therefore, erected the Jaya Prakāś, the Rāma, and the Samrāt instruments which were perfectly stable and built in mortar and stone, whose semi-diameters were 18 cubits, and one grain (yava) in the circumference of which would represent 1 minute of arc. These were constructed and erected with due consideration of geometrical theory, the meridian,and latitude of the place and with careful measurements. They were so designed that it wold be possible to repair the defects caused by the sinking of circular planes, wearing out of axes, shifing of the central points, and irregular spacing of minute divisions. An observatory of this type was built at Delhi. Corrections to be applied to mean motions of planets, which never agreed with observation, were finally determined on the basis of observations taken with these instruments. In order to test the correctness of results of observations taken at the Delhi observatory, he erected similar observatories at Sawai, Jaipur, Mathura, Vāranasī and Ujjayinī. Observations taken at all these places tallied with one another. After seven years were spent in taking these observations, it was learnt that similar work was being done in Europe also. Hence, MANUEL, the priest and some other scholars were sent there and the planetary tables compiled 30 years ago and published in the name of *LIEL**, were brought through them. The calculations made from them, however, did not agree with observations; it was found that there was an error of about 1/2 degree and some perceptible etror in the case of other planets. Hence, under the direction of the Emperor, a work was compiled containing formulae and mathematical processes for calculation, which were very precise and correct. Its calculation exactly tallies with observation. (The emperor's name was given to the work as a mark of honour.)"

HUNTER, visited four out of the five observatories about the year 1799 A. D. and wrote their description in the "Asiatic Researches" mentioned above. It is not given in full for want of space. The description of the observatory at Vārānasī, as given by Sherring (1868 A. D.) in his English book

†He was on the throne at Delhi from 1720 to 1748 A. D.

*Jayasiṃha completed the compilation of his work in 1141 Hijrī era (i.e. 1728 A.D or Saka 1650). The work brought from Europe was of De Levarrior. It was first published in 1678 A. D. and then again in 1702 A. D.

(2) ADHIKĀRA ON TRUE PLACES

Chapter 1

True places and motions of planets

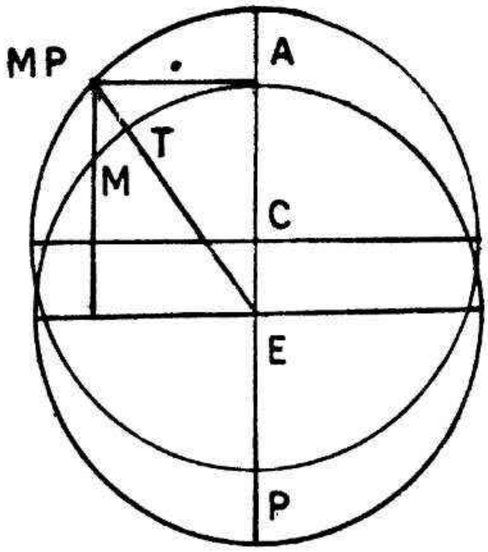
A planet is not found moving every day at its mean daily rate of motion which is obtained from the time it takes to make a complete revolution through the Zodiac, but at a greater or smaller rate ; and hence, on a given day it is not seen actually occupying the place in the sky which is found from its mean motion by calculation. The position and motion of a planet as actually seen in the sky are called its true (spaṣṭa) place and motion. It is the subject of study for the chapter on true places to find the true position and motion of a planet from its calculated mean position and motion. [It is a convention with our w rks to speak of the true position of a planet as "true planet" (spaṣṭa graha) and hence, this term is so used in some places in the following discussion.]

The chief reason why the true motions of the Sun and Moon differ from their mean motions is that according to the laws of planetary motions, which are now almost universally recognized, and which were first discovered by *Copernicus*, and verified and firmly established by *Kepler* and *Newton*, the earth revolves round the Sun, and the Moon round the earth in an elliptical orbit ; and there are two reasons why the true motions the remaining five planets differ from their mean motions ; Mercury and the other four planets revolve round the Sun in an elliptical path, which gives them in their orbits a position different from their mean positions and the other reason is that this position of planets relative to the Sun, appears still different to us (observers on the earth), since the earth constantly changes its position in the sky while revolving round the Sun.

Although our ancient astronomers did not know these reasons in thei r real perspective—two reasons in the case of five planets and one in the case of the Sun and Moon, they have unknowingly assumed the same principles to start with, while finding the places of planets ; and the true positions of planets which we obtain by following our works agree to a considerable extent, if not to the fullest extent, with those obtained by following the methods which the Westerners have established after understanding the theory. In other words, the mean position of a planet being the same, if it be found by Western methods of calculation occupying a particulars place in the sky, we too get the same or very nearly the same place by following our own works ; and the difference, if any, in the two results is due to some slight defects or approximations of the elements assumed in our calculations, and also to the fact that some other elements, in addition to the above two reasons, which have been lately discovered, were not known to our people. The following discussion will confirm the truth of the above statement that the two main reasons were indirectly known to our astronomers.

The theory underlying the method of calculating the true place of a planet from its mean place is explained in our works by means of a diagram. Here the theory is given, as it will help one to understand what the reasons are which cause a difference between the true and the mean place of a planet, and what the ideas of our astronomers were reparding this question. They draw

a circle to represent the planetary orbit, having for its centre, the centre of the earth. They draw another circle, equal to the first, such that its centre will be at a distance from the earth's centre. This circle is termed a '*Prativṛtta*' (eccentric circle) ; and the mean planet is supposed to move in that circular orbit, and the point of the planetary orbit which the mean planet would appear to occupy would be said to be its true place.



In the adjoining figure the circle whose centre is E is the planet's orbit. Similarly, the 'eccentric' circle has been drawn with C as its centre ; and point 'M.P.' in it represents the position of the mean planet and M, the corresponding position of the mean planet in its orbit. To an observer on the earth, the mean planet appears to lie in the line joining the point 'M.P.' to E. This line is called the 'Karṇa' (radius vector). This radius vector cuts the orbit circle at T, and the true planet appears to be in the orbit circle at that point. The difference between the true and the mean place, viz. the arc MT (i.e. MET))is termed '*phalasaṃskār*' (i.e. equation of centre). The maximum value of this correction is called the 'parama' or 'antya'-phalasaṃskār (max. equ. of centre). The centre C of the eccentric circle is marked away from E, the centre of the orbit circle, at a distance equal to the sine of the maximum correction. The 'phala' (i.e. correction) mentioned above, is called 'mandaphala' i.e. equation of centre. The position obtained by applying this correction, or equation of centre, to the mean place of a planet (i.e. adding the correction to or subtracting it from the mean place, according as it is positive or negative) is termed the 'manda-spaṣṭagraha' (true heliocentric place of a planet). The true places of the Sun and Moon are obtained by applying only one correction, that of the equation of centre. But, the positions so obtained in the case of other five planets are not the positions at which they would be visible to observers on the earth ; (according to modern theory they will represent the true heliocentric position, that is the position seen from the centre of the Sun). They require another correction to be applied ; it is called the '*Śīghra-phala-saṃskār*' (i.e. the annual parallax). When it is applied to the heliocentric position, one gets the position where the planet is observed from the earth. In order to find it, they assume another circle called the '*Śīghra-prati-vṛtta*' (śīghra eccentric circle) and they find the required correction by regarding the position of the heliocentric planet as that of the mean planet. The operation of obtaining the 'mandaphala' (equation of centre) is known as the 'manda-karma' and that of obtaining 'śīghra-phala' (annual parallax), as 'śīghra-karma'. The method of finding the 'śīghra phala' is expalined below :—

The orbit circle drawn in the operation of "manda karma" becomes the "śīghra-prativṛtta" in the operation of "śīghra-karma", then taking a point away from the centre of this circle, at a distance equal to the sine of the maximum value of 'śīghraphala', another orbit circle is drawn with this point as centre.

The earth itself is supposed to be at the centre of this orbit circle drawn in the operation of 'śīghra-karma'.The place where the heliocentric planet, while moving at its own rate of motion in the "śīghra-prati-vṛtta", appears to be in the "śīghra-kakṣāvṛtta" is its geocentric position. The planet appears to be at that place to an observer on the earth. Some people treat the "manda-kakṣāvṛtta" itself as the "śīghra-kakṣāvṛtta", and then they draw an equal circle called the "śīghra prativṛtta", having for its centre a point which is marked at a distance equal to the sine of 'śīghrāntya-phala', from the original centre. Then the heliocentric position of the planet from the 'mandakakṣāvṛtta' is transferred to the "śīghra-prativṛtta", and its place as seen in the "kakṣāvṛtta" is taken to be its geocentric position. Both the methods lead to the same result.

The above diagram will show that the distance of the planet moving in the eccentric circle is not the same from the point E. The distance is greatest when the planet is at A (aphelion) and the least when it is at P (perihelion); in other words, the path of the moving planet is as it were assumed to be, elliptical. E is one focus of this ellipse.

Parameśwara, the commentator of Āryabhaṭīya, has described in simple words, the method of drawing the figure for finding the equation of centre The author has not come across an equally good explanation in any other work. The author, therefore, quotes the verses here :—

त्रिज्याकृतं कुमध्यं कक्षावृत्तं भवेत् तु तच्छैघ्रयं ॥
शीघ्रदिशि तस्य केंद्रात् शीघ्रांत्यफलांतरे पुनः केंद्रं ॥ २ ॥
कृत्वा विलिखेत् वृत्तं शीघ्रप्रतिमंडलाख्यमुदितमिदं ॥
इदमेव भवेन्मांदे कक्षावृत्तं पुनस्तु तत्केंद्रात् ॥ ३ ॥
केंद्रं कृत्वा मंदांत्यफलांतरे वृत्तमपि च मंददिशि ॥
कुर्यात्प्रतिमंडलमिदमुदितं मांदं शनीड्यभूपुत्राः ॥ ४ ॥
मांदप्रतिमंडलगास्तत्कक्षायां तु यत्र लक्ष्यंते ॥
तत्र हि तेषां मंदस्फुटाः प्रदिष्टास्तथैव शैघ्रे ते॥ ५ ॥
प्रतिमंडले स्थिताः स्युस्ते लक्ष्यंते पुनस्तु शैघ्राख्ये ॥
कक्षावृत्ते यस्मिन् भागे तत्र स्फुटग्रहास्ते स्युः ॥ ६ ॥
मांदं कक्षावृत्तं प्रथमं बुधशुक्रयोः कुमध्यं स्यात् ॥
तत्केंद्रान्मंददिशि मंदांत्यफलांतरे तु मध्यं स्यात् ॥ ९ ॥
मांदप्रतिमंडलस्य तस्मिन् यत्र स्थितो रविस्तत्र ॥
प्रतिमंडलस्य मध्यं शैघ्रस्य तस्य मानमपि च गदितं ॥ १० ॥
शीघ्रस्ववृत्ततुल्यं तस्मिश्चरतः सदा ज्ञशुक्रौच ॥

"The orbit circle, at the centre of which is the earth, and whose radius is equal to 'trijyā' *is called a 'śaighra' circle (i.e. the orbit circle necessary in the geo-

*The word 'trijyā' is now-a-days used as a technical term signifying semi-diameter. But originally it stood for 'jyā' (sine) of 'tribha' (i.e. 3 signs or 90 degrees); and our astronomical works are generally found using it in that sense. When the perimeter of a circle is supposed to consist of 360°, (or 21600 minutes), the semi-diameter becomes equal to 3438'; or the sine of 90° is equal to the semi-diameter. Hence, by "trijyā" is generally meant a line whose length is 3438'.

centric calculation or 'śīghra-karma'). Another circle should be drawn with a point for its centre, which should be away from the centre (of the orbit circle) at a distance equal to maximum 'śīghra phala' and in the direction of the 'śīghra' position. This circle is termed as 'śīghra'-eccentric circle. The same becomes a 'kakṣāvṛtta' (orbit circle) in the heliocentric operation. Again, draw another circle, in the direction of the heliocentric position, having its centre at a distance of maximum equation of centre. This is termed 'manda'-eccentric circle. Saturn, Jupiter and Mars, while moving in the 'manda eccentric circle' are seen occupying certain places in the heliocentric orbit circle, and they are termed 'heliocentric'. (These are the heliocentric positions of Saturn, Jupiter, and Mars). They should similarly be treated as moving in the 'śīghra'-eccentric circle and their corresponding positions in the 'śīghra'-orbit circle would be called their 'true position' (These should be taken to be their geocentric positions). The circle having the earth for its centre, becomes the 'Manda' orbit circle for Mercury and Venus. The centres of their 'manda' eccentric circles lie at a distance, equal to their maximum equation of centre, from the centre of the orbit. The point of this circle occupied by the Sun should be taken to be the centre of the geocentric eccentric circle. The size of this circle has been mentioned as being equal to that of his 'own-geocentric-circle'. Mercury and Venus always move in that circle.

The underlying theory of the equation of centre is explained in another way by assuming a circle known as the 'nīcocca-vṛtta' (apsidal circle). BHĀSKARĀCĀRYA observes in this connexion :—

कक्षास्थमध्यग्रहचिन्हतोथ वृत्तं लिखेदंत्यफलज्यया तत् ।।
नीचोच्चसंज्ञं रचयेच्च रेखां कुमध्यतो मध्यखगोपरिस्थां ।। २४ ।।
कुमध्यतो दूरतरे प्रदेशे रेखायुते तुंगमिह प्रकल्प्यं ।।
नीचं तथासन्नतरेऽथ तिर्यङ् नीचोच्चमध्ये रचयेच्चरेखां ।। २५ ।।
नीचोच्चवृत्ते भगणांकितेस्मिन् मांदे विलामं निजकेंद्रगत्या ।।
शैघ्रयेऽनुलोमं भ्रमति स्वतुंगादारभ्य मध्यद्युचरो हि यस्मात् ।। २६ ।।
अतो यथोक्तं मृदुशीघ्रकेंद्रं देयं निजोच्चाद्युचरस्तदग्रे ।।

छेद्यकाधिकार.

"Draw a circle with the mean planet in the orbit, as centre, and the sine of maximum equation of centre as the radius. It is called 'the apsidal' circle. Draw a line from the centre of the earth passing through the mean planet. It intersects the circumference of the epicycle in two points—the farthest point is called the 'ucca' (aphelion) and the nearest one the 'nīca' (perihelion). Draw a horizontal line in between the aphelion and perihelion. Mark the signs and degrees on the circumference of the 'nīcocca'- circle. The mean planet moves from the aphelion in the mānda (heliocentric) epicycle in a regular direction, and in the Śaighra (geocentric) epicycle in a reverse direction, at the same rate of motion as its anomaly (i.e. according to the motion of its mean anomaly or of the angle of commutation). Hence, the centres of the mean and true circles are to be marked in relation to the aphelion.

equation of centre is Zero. As the planet advances three signs or 90° from the aphelion, the value of the equation of centre gradually increases and then it continually decreases till it reaches the perihelion. It increases again for three signs more and finally decreases till it reaches the aphelion. In short, whatever change occurs in the mean motion of the planet is in relation to the aphelion. The Sūrya Siddhānta makes the following observation :—

अदृश्यरूपाः कालस्य मूर्तयो भगणाश्रिताः । शीघ्रमंदोच्च पाताख्या ग्रहाणां गतिहेतवः ॥ १ ॥

तद्वातरश्मिभिर्बद्धास्तैः सव्येतरपाणिभिः । प्राक्पश्चादपकृष्यंते यथासन्नं स्वदिङ्मुखं ॥ २ ॥

स्पष्टाधिकार.

" The three invisible forms of time, viz. śīghrocca, mandocca and pāta which are supported by 'bhagaṇas '(revolutions) are the generators of the motions*of planets. These forms of time drag towards themselves by tossing and fro**, the planets which are tied by the reins of wind held by them."

No other siddhānta has given so much importance to the aphelia as the S. S. has done by regarding them as some animate objects. *Brahmagupta* simply remarks,

प्रतिपादनार्थमुच्चा : प्रकल्पिता*** : ग्रहगतेस्तथा पाताः ॥ २६ ॥

गोलाध्याय.

" The aphelia and nodes have been imagined as points simply to explain the phenomena of planetary motions. "

Nowhere does the S. S. explicitly state that the planets move in the epicyclic orbits ; hence, it appears that the aphelia have been supposed to be some objects having forms. But when the planets are assumed to be moving in epicyclic orbits, their mean positions naturally undergo a change which simply depends upon the distance of the planet from the aphelion.

It has been mentioned above that the epicycles are supposed to be drawn at a distance from the centre of the orbit circle equal to the sine of the maximum value of the equation of centre or the annual parallax. The value of the equation of centre or of the annual parallax concerning each planet is given in our treatises, and it is the convention to give it in terms of the circumference of a circle, having the sine of maximum correction (viz. equation of centre) as semi-diameter ; in other words it is what the length of the *circumference*, expressed in degrees, would be, if a circle be drawn with the sine of maximum correction as semi-diameter ; and it is generally termed ' Paridhi ' or ' circumference '. The circumference of the circle drawn with respect to the equation of centre is called the " mandaparidhi " i.e. the dimension of the epicycle of the apsis, and that with respect to the annual parallax is called the ' śīghraparidhi ' or the dimension of the epicycle of the apex. The reason for expressing the equations in terms of epicycles seems to be the above system of drawing the epicycles of apsides. Considered independently, the circumference of the apsidal circle no doubt represents 360° ; but as the value of the equation is to be reckoned in terms of degrees of the orbit circle, the length of the perimeter of an epicycle is also expressed by the same system of degrees.

*Here, the word ' motion ' is to be taken to mean true motion.

**By " to and fro " is meant the actual position in advance of or behind the mean position of a planet. (Ranganātha has interpreted this in a somewhat different way). The position of a planet in the north or south direction changes because of the nodes.

***By ' motion ' here is meant the true motion of the planet.

The next table gives the dimensions of the epicycles related to the apsis and the apex as given by different authors ; similarly, their radii also have been calculated and given. The radii themselves represent the maximum values of their equations. While calculating the radius, the ratio of the circumference to its radius as mentioned by Āryabhaṭa I and Bhāskarācārya, viz. 62832 : 10000, has been adopted.

The arc of anomaly containing 3 signs or 90° is termed '*pada*' quadrant). The first and third are termed '*oja*' (odd) and the second and fourth '*Yugma*' (*even*). The authors of some siddhāntas hold the view that the length of the circumference related to the odd quadrants is different from that of the circumference of the even quadrants ; and that it varies in the intermediate portions proportionately. In the following table, the *paridhis* of some planets according to the Pañcasiddhāntikā have not been given, because the figures as given in that work are not known for certainity. In the case of other siddhāntas, wherever the paridhis related to the even quadrants are not mentioned, they are to be taken to be equal to those related to the odd quadrants.

MANDAPARIDHI

Dimensions of the Epicycles of Apsis and their radii or max. value of the equation of centre .

Planet	The S. S. from Paca Siddhān/tikā		Modern Sūrya Siddhānta: At the end of odd quadrant		Modern Sūrya Siddhānta: At the end of even quadrant		First Ārya siddhānta: At the end of odd quadrant	
	Circum	Radius	Circum	Radius	Circum	Radius	Circum	Radius
	°	° ′ ″	° ′	° ′ ″	°	° ′ ″	° ′	° ′ ″
Sun	14	2 13 41	13 40	2 10 30	14	2 13 41	13 30	2 8 55
Moon	31	4 56 2	31 40	5 2 24	32	5 5 35	31 30	5 0 48
Mars	70	14 8 27	72	11 27 33	75	11 56 12	63 0	10 1 36
Mercury	28	4 27 23	28	4 27 23	30	4 46 29	31 30	5 0 48
Jupiter	32	5 5 35	32	5 5 35	33	5 15 8	31 30	5 0 48
Venus			11	1 45 2	12	1 54 35	8 0	2 5 53
Saturn			48	7 38 22	49	7 47 55	40 30	6 26 45

Planet	First Ārya Siddhānta: At the end of even quadrant		Brahma Siddhānta: At the end of odd quadrant		Brahma Siddhānta: At the end of even quadrant		Second Ārya Siddhānta	
	Circum	Radius	Circum	Radius	Circum	Radius	Circum	Radius
	° ′	° ′ ″	° ′	′ ″	°	° ′ ″	° ′	° ′ ″
Sun			13 40	2 10 30			13 40	2 10 30
Moon			31 36	5 1 45			31 34	5 1 26
Mars	81 0	12 53 29	70 0	11 8 27			65 30	10 25 29
Mercury	22 30	3 34 51	38 0	6 2 52			27 36	4 23 34
Jupiter	36 0	5 43 46	33 0	5 15 8			28 15	4 29 46
Venus	9 0	1 25 57	9 0	1 25 57	11	1 45 2	9 35	1 31 31
Saturn	58 30	9 18 38	30 0	4 46 29			52 42	8 23 15

Dimensions of the EPICYCLES OF APEX and their radii or max. value of the annual parallax.

Planet	The S. S. from Pañca Siddhāntikā		Modern Sūrya Siddhānta At the end of odd quadrant		Modern Sūrya Siddhānta At end end of even quadrant		First Ārya Siddhānta At end end of odd quadrant	
	Circum	Radius	Circum	Radius	Circum	Radius	Circum	Radius
	°	° ′ ″	°	° ′ ″	°	° ′ ″	° ′	° ′ ″
Mars	234	37 14 32	232	36 55 26	235	37 24 5	238 30	37 57 30
Mercury	142	21 0 30	132	21 0 30	133	21 10 3	139 30	22 12 7
Jupiter	72	11 27 33	72	11 27 33	70	11 8 27	72 0	11 27 33
Venus	260	41 22 49	260	41 22 49	262	41 41 55	265 30	42 15 20
Saturn	40	6 21 58	40	6 21 58	39	6 12 25	40 30	6 26 45

Planet	First Ārya Siddhānta At the end of even quadrant		First Ārya Siddhānta At the end of odd quadrant		Brahma Siddhānta At the end of even quadrant		Second Ārya Siddhānta At the end of odd quadrant	
	Circum ° ′	Radius ° ′ ″	Circum ° ′	Radius ° ′ ″	Circum	Radius	Circum ° ′	Radius ° ′ ″
Mars	229 30	36 31 33	243 40	38 46 50	°	° ′ ″	230 59	36 45 43
Marcnry	130 30	20 46 11	132	21 0 30			134 30	21 24 23
Jupiter	67 30	10 44 35	68	10 49 21			69 30	11 3 40
Venus	256 30	40 49 23	263	41 51 28	258	41 3 43	261 30	41 37 8
Saturn	36 0	5 43 46	35	5 34 13			40 40	6 28 20

The maximum values of the equation of centre according to Ptolemy and those according to modern European astoronomers have been given below in a table.* One can, of course, compare them with the above values given in our old treatises. But in order to facilitate such comparison, the maximum values of the equation of centre at the end of the odd quadrants as given by Āryabhaṭa I, out of our siddhāntas, have again been given below :—

MAXIMUM VALUES OF EQUATION OF CENTRE

	First Ārya Siddhānta	Ptolemy	Modern
	° ′ ″	° ′	° ′ ″
Sun	2 8 55	2 23	1 25 27
Moon	5 0 48	5 1	6 17 13
Mars	10 1 36	11 32	10 41 33
Mercury	5 0 48	2 52	23 40 43
Jupiter	5 0 48	5 16	5 31 14
Venus	2 51 53	2 23	0 47 11
Saturn	6 26 45	6 32	6 26 12

*These have been adopted from the translation of the Sūrya Siddhānta by Burgess (p. 76).

The modern values of Mercury and Venus cannot properly be compared with those given in our works, because the modern values are true only with respect to an observer on the Sun's disc while our works have given them with regard to the observer on the earth. It would not be wrong, however, if the values of other planets from both the systems are compared ; and when they are so compared, it will be seen that the values given in our works agree with the modern ones to a great extent. The orbits of the moon and the planets are elliptical according to the modern astronomical theory. The value of their equation of centre varies with the changing values of the eccentricity of their orbits ; and these values of the equation of centre as given in our works agree with the values given in modern works. The form of planetary motions as given in our works has been shown above which will show that although the writers of our works have not assumed an elliptical orbit for the movement of planets, still they have assumed that their distances from the centre of the orbit never remain the same, and that the equations vary with their position with respect to the points of apices known as aphelion and perihelion, in the orbit ; from this it would appear that ancient authors indirectly knew the main cause of the difference between the true and mean places of planets, that is the phenomenon of the movement of these planets (or of the Moon) in elliptical orbits. The annual parallax of a planet depends upon the variable distance of the planet's heliocentric position in its orbit from the earth. 'The figures showing the annual parallax as given in our works have been given in the above table (page 243) and it has been pointed out before (page 197)' that the radii vectors of planets calculated from them agree with the corresponding modern values. This fact coupled with the trend of the above discussion will show that our astronomers indirectly knew the second factor which was responsible for the difference between the true and mean position of a planet,—that the position of a planet with respect to the Sun, which is known as its heliocentric position, differs from the positions seen by an observer on the earth, because the earth also revolves round the Sun.

That none of the values given by PTOLEMY agree with the corresponding values given in our siddhāntas is one out of the many proofs* to show that Ptolemy had no concern with any of the siddhāntas.

Now some more noteworthy facts about the epicycles of apsides and apices may be mentioned. According to some siddhāntas, the dimensions of epicycles are different in the odd and even quadrants. ĀRYABHAṬA I has shown much variation in these dimensions ; the Sūrya Siddhānta does not mention so much variation. BRAHMAGUPTA has assumed different dimensions for the epicycles in the odd and even quadrants only in the case of Venus. The modern Romaśa, Soma, Śākalya Brahmasiddhānta and Vasiṣṭha siddhānta are almost similar to the modern Sūryasiddhānta ; still the measures of epicycles, as given in the Romaśa and Soma have been assumed to be the same throughout, and they agree with those of the even quadrants mentioned by the S. S. The dimension of the apsidal epicycle of mercury, given by Soma siddhānta as 34, however, does not agree (with S. S.). The Vasiṣṭha

*The Romaka siddhānta of the Pañcasiddhāntikā gives 4°57′ as the maximum equation of centre for the Moon (See 8.6. Pañc S.). This does not agree with that given by Ptolemy. This is one of the proofs to show that the Romaka Siddhānta of the Pañca Siddhāntikā was not written by Ptolemy.

siddhānta does not mention* the apsidal epicycles at all. The dimensions of the epicycles of the apices have been given, but they do not agree with those of the Sūryasiddhānta, and hence they are given below :—

Mars 234 ; Mercury 133 ; Jupiter 71 ; Venus 261 ; Satur 39.

Theses are the same for both the quadrants, and though they do not agree with the Sūrya Sidhānta, they are easily seen to be approximately mean measures of the two kinds of quadrants. The copy of the Śakalya Brahma siddhānta in the author's possession does not mention any epicycles at all ; but there undoubtedly appears** to be in this copy, a break at the place where they are expected to have been mentioned. They must have been given in the original work. *Lalla* being the follower of Āryabhata I, the measures of epicycles given by both of them are indentical. Similarly BHĀSKARĀCĀRYA was the follower of Brahmagupta and both have therefore, given the same measures. But Bhāskarācārya has mentioned 50° as the measure of the apsidal epicycle of Saturn and 40° as that of its epicycles of apex. The Sundursiddhānta of JNĀNARĀJA has given measures of epicycles similar to those of the modern Surya Siddhānta. According to Munisẃara,, the author of Siddhānta Sārvabhauma, it is illogical to asume different measures for the epicycles in the odd and even quandrants. He has given the mean values of the measures of the epicycles in the odd and even quadrants given in the modern Surya Siddhānta. Different Karaṇa works show some variations the measures of epicycles ; but it appears to be due to the fact that sufficient attention was not paid to their accuracy. There is nothing specially worth mentioning about them.

The modern values of the equations of centre are given above ; but they are not always the same. They very with the lapse of time. The following table *** gives an idea of the long-period variation affecting the value of the Sun's equation of centre.

Years before Śaka era	Maximum value of eqn. of centre °	′	Years after Śaka era	Maximum value of eqn of centre °	′
10000	2	31	0	2	1
9000	2	28	1000	1	58
8000	2	25	2000	1	55
7000	2	22	3000	1	52
6000	2	19	4000	1	49
5000	2	16	5000	1	46
4000	2	13	6000	1	43
3000	2	10	7000	1	40
2000	2	7	8000	1	37
1000	2	4	9000	1	34
0	2	1	10000	1	31

* It is found neither in the edition printed at Varanasi nor in the version in the Deccan College collection.

** The second chapter begins abruptly after an incomplete line of the verse : "Maurvya Catuṣke", which is given after 111 verses of the first chapter. The second chapter opens with an unexpected question. It seems that the epicycles may have been mentioned in between. It is surprising that the break was found precisely at the same place in the copies seen at Gwalior, Asta, and later on in the Anandāśrama copy (No. 4341).

*** This table has been taken from the Planetary Tables of Keropant.

The table shows that the correction due to the equation of centre, in the case of the Sun, is gradually diminishing. This correction, according to our works, ranges from 2° 13′ 41″ to 2° 8′ 55″. It may be noticed that the more ancient treatises have given a greater value and the modern works a smaller one, as can be seen from the above table (page 242). It is easily seen that the value was determined after actual observations were taken at different times. Our astronomers have determined the correction figures for the Sun and Moon from the observations of their eclipses, that is from their positions at the moments of lunations. The modern European method of finding the true place of the Moon from that of its mean place, requires the application of five main corrections. It has been shown further that our people had determined a value as the maximum equation of centre for the moon, which is equal to the sum of the four (out of five) corrections applicable at the moment of lunation. The maximum value of the fifth correction of the equation of centre is 11 minutes. (Planetary Tables, by Keropant, p. 105). As its argument is Sun's anomaly, it was taken to be applicable to the Sun with minus or plus sign, where it was actually to be applied to the Moon with plus or minus sign. This has not affected the result of the calculation of the eclipse. If 11′ be subtracted from 2° 14′, which is the value of the sun's maximum equation of centre as given in our ancient works, our works can, in fact, be said to have given 2° 3′ as the correction for the Sun, and that was actually the value in the year 500 B.S. Hence, our people appear to have found out the cerrection for the Sun at that early period or at least two or three centuries before Śaka era. The equation of centre for the Sun, according to Ptolemy, is 2° 23′, which means that he had nothing to do with our works. Although PTOLEMY has given 2° 23′ as the Sun's correction, it was actually 2° in his time (about Śaka 70). Obviously it was not found by *Ptolemy* himself, but probably adopted from some previous writer. The fact that no one except *Hipparchus* possessed, before him, the knowledge of calculating the true place of the Sun and the fact that the length of the year according to Ptolemy and Hipparchus was the same* measure ($365^d\ 14^g - 48^p$) lead one to infer that Ptolemy had adopted the value of the Sun's equation of centre from Hipparchus. This inference is further confirmed by the fact that the Romaka siddhānta which was compiled on the basis of the work on Hipparchus has adopted 2° 23′ 23″ as the maximum equation of centre for the Sun. No one ever says that the Hindus borrowed astronomy from some work compiled after Ptolemy. No astronomer of equal capability flourished within 3 or 4 centuries after Ptolemy. None of our Siddhāntas contain the same equation of centre for the Sun as was given in the original Romaka Siddhānta. From all these facts, any impartial thinker will have to admit that it is proved beyond all doubt that our astronomers did not borrow the figures for the equation of centre for the Sun from any European work, but that they themselves determined it before the Śaka era.

The modern maximum values of the equation of centre that have been given above (page 242) show that the equation of centre for the moon is 6° 17′. But there are certain factors, other than the equation of centre, which cause a difference between the Moon's mean and true places ; and these sometimes cause a variation of 8° to 8½° between the mean and true places of the Moon. For finding this, about 40 corrections are required to be applied. Of these, the correction known as the equation of centre, mentioned above, is a very large figure and the other four corrections are also appreciably large. Of

*Grant's *History of Physical Astronomy*, Chap. XVIII.

these, the one known as 'variation' (pākṣika or taithik) has "moon *minus* true sun" as its argument. This argument will, of course, become 6 signs and zero at the moment of the full moon and the new moon respectively, and this correction too becomes zero* at these moments. Similarly, for calculating the second of the four corrections, known as "evection" (cyuti), the argument is [2×(corrected moon—true sun) —moon's anomaly].

The first term in this formula becomes zero at the moment of the full moon and new moon ; and the argument is reduced to (zero *minus* moon's anomaly) at that moment. When the value of the argument is three or nine signs, the correction attains its maximum value viz. 1° 20.2′. Hence, if the moon's anomaly at the time of the full or new moon is 3 or 9 signs, the argument for calculating the correction due to evection becomes "zero minus three signs" i.e. 9 signs or 'zero *minus* nine signs' i.e. 3 signs and the corresponding values of the correction due to evection become respectively +1° 20′ and —1° 20′**, and at that time, if the moon's anomaly is 3 signs, the equ. of centre becomes —6° 17′ and if the moon's anomaly is 9 signs, the equ. of centre becomes +6° 17′***.

Hence at the moments of full or new moon, the maximum value of the correction, as given by the equation of centre and the evection together, would not exceed $\pm 1° 20' \mp 6° 17' = \mp 4° 57'$.

One correction of 11′ out of the four has been applied to the Sun as already explained. The fourth correction is about 7 minutes.**** Applying it to the above figure of 4° 57′, we get 5° 4′. The remaining 35 out of 40 corrections are very small. In short, the maximum value of the moon's equation of centre as given by our siddhāntas, which lies between 4° 56′ and 5° 6′, has proved to be very accurate†. The best means of testing the accuracy of the values of the equations of centre in the case of the sun and moon are the eclipses ; and it has already been observed before (pages 60, 130 etc.), that our astronomers have determined the corrections for the Sun and Moon with the aid of the eclipses.

Sudhākara states that *Munjāl* has mentioned a correction similar to that of evection and another like variation, and that *Nityānanda* has mentioned those for variation and for the nodes.

No Western astronomer before *Ptolemy* knew how to find the true places of the five planets ; even *Hipparchus* did not know it††. And the maximum values of the equation as given by Ptolemy do not agree with those given in our works. This shows that our astronomers have themselves found out the method of calculating the true places of the five planets. The calculation of the true places of the Sun, Moon and the five planets is the most important part of mathematical astronomy ; in fact it is the quintessence of astronomy, and this we have decidedly not borrowed from Westerners.

* Keropant's Planetary Tables, p. 110.

** Keropant's Planetary Tables, p. 106.

*** Keropant's Planetary Tables, p. 109.

**** Keropant's Planatary Tables, pp. 105 & 111.

† The above explanation about the equation of centre relating to the Sun and Moon was suggested by Venkateś Bāpūji Ketkar.

††Grant's *History of Physical Astronomy*, Chap. XVIII.

The equation of centre is found by the formula

$$\frac{\textit{epicycle X sine of anomaly of planet.}}{\text{semi-diameter}}$$

The 'Kendra' (anomaly) is the difference between the place of the planet and that of the aphelion. The Sun and Moon require only one correction, that of the equation of centre. Others require two corrections, the equation of centre and the annual parallax. The calculation requires the use of the planet's distance from the earth ; and in order to find the equation of centre accurately, one has to use the method of successive approximation.

Sines and Radius

The siddhānta works give sines of divisions of circle, each of which is equal to 3¾°. The Karaṇa works use divisions consisting of 10° to 15° each since they are not very particular about accuracy. Most of the siddhāntas have assumed 3438 as the value of 'trijyā' (radius) while calculating values of sines. Brahmagupta has assumed it to be 3270. Kamalākara, the author of Siddhāntatattva-viveka has mentioned sines of each degree of the quadrant assuming 60 as the value of the 'trijyā'. The Karaṇa works generally take 120 as the value of the trijyā. According to Sudhākara, Munjāl has adopted 8° 8′ as the 'trijyā' and Gangādhara, author of Cāndramāna (page 195) has adopted 191 as the measure. The work Yantrarāj has adopted 3600 as the 'trijyā' and given the sine of each degree of the quadrant. Keropant Nānā remarks* that the value of 'trijyā', 3438, which this Hindu astronomers adopt is an awkward figure entailing unnecessary multiplication and division. This is to a certain extent, true. But our astronomers have at places made use of artifices to avoid lengthy multiplications and divisions ; and the reason for adopting that figure for the radius is a rational one, inasmuch as the circumference of the circle is equal to 21600 minutes and the radius computed from it comes to 3438. The most accurate ratio of the diameter to the circumference is 1 : 3·1415927. On the basis of this ratio, if the circumference be 21600, the semidiameter comes to 3437¾. Our astronomers have adopted 3438 as the value after leaving out the fraction. This will show that the value of 'trijyā' adopted by our astronomers is very accurate†. Our ancient authors have assumed different figures as the ratio of the diameter to the circumference. They are given below :—

Sūrya Siddhānta, Brahmagupta, Āryabhaṭa II	.. 1 : $\sqrt{10}$ or 1 : 3.1623
Āryabhṭa I	.. 20000 : 62832 or 1:3.1416
Āryabhaṭa II & Bhāskarācārya**	.. 7 : 22 or 1 : 3.1428
Bhāskarācārya	.. 1250 : 3927 or 1 : 3.1416
3438 as the radius gives	.. 1 : 3.14136
Precise Modern European value	.. 1 : 3.1415927

Evidently our people had a very accurate knowledge of the ratio of the diameter to the circumference. If they have, at places, adopted an approximate value, it is only with a view to simplifying calculations in practical work.

---

* See Planetary Tables, page 314.

† The European mathematicians assume the value of a 'tryijā' as equal to the 10th or some other power of 10. They have ready made tables for the purpose, which give sines and other ratios of each minute of arc ; and as the trijyā is a very large number greater accuracy is ensured.

** Āryabhaṭa II and Bhāskarācārya each has mentioned this ratio in two ways.

Brahmagupta has given in the following verse the reasons for adopting 3270 as the value of the semi-diameter :—

भगणकलाव्यासार्धं भवति कलाभिर्यतो न सकलाभिः
ज्यार्धानि न स्फुटानि ततः कृतं व्यासदलमन्यत् ॥ १६ ॥

गोलाध्याय.

Accurate calculation shows that the radius, corresponding to 21600 as the circumference, is not the whole number 3438, and it is true that because of this the "first sines" are not very accurate. But the author does not think that the value of the semi-diameter viz. 3270 which Brahmagupta has adopted on the basis of the ratio 1 : $\sqrt{10}$ of the diameter to the circumference or by some other method can be justified.

The question of calculating sines and their origin has been dealt with as great length by Bhāskarācārya. Even the author of Siddhāntatattvaviveka has given much thought to it. It is not necessary to deal with it here in detail. Playfair (1782 A.D.), an European scholar, observes about the origin of sines in our treatises, "The method devised by Hindu astronomers to find the sines implies the following proposition* :—'The ratio of the sum of the sines of the first and the last of three arcs in arithmetical progression to twice the sine of the middle one is equal to the ratio of the cosine of the difference of the arcs to the radius'—This proposition was apparently not known to European mathematicians till the beginning of the 17th century". It is really creditable to our people. Similarly the Greeks only knew what a chord is, but they did not know to make use of the first sines (jyārdha). Even the Arabs didn't know of it till the 9th century A.D. It has been pointed out in the account of Āryabhaṭa I that it was known to our astronomers from Śaka 421. Our people, however, did not have an idea of the tangent and the secant. Their purpose was, however, served by sines alone.

OTHER MATTERS

The question of finding when planets become direct or retrograde and when they rise and set, these and other like matters of secondary importance are dealt with in the chapter on true motions. It is not necessary to deal with them at length here.

DECLINATION

Our works assume 24° as the maximum declination of the Sun. The obliquity of the ecliptic had reached that value 2400 years before the aka era. It is 23° 27′ 10″ in the beginning of śaka 1818. This means that the maximum declination at the present time, as calculated from our wo rks, is wrong by 32′ 50″. The obliquity about Śaka 400 was about 23° 39′. Ptolemy's work (SYNTAXIS, Part I) mentions it as a value lying between 23° 50′ and 23° 52′ 30″, and it seems to be Prof. Whitney's opinion** that he borrowed this value from the works of Hipparchus. As this value of obliquity does not agree with the value given in our works, it is obvious that our people did not borrow their figure from the works of Hipparchus and Ptolemy. They must, of course, have found it independently and some time before the Śaka era. The work entitled, Yantrarāj, assumes 23° 35′ to be the obliquity. (In fact, this was correct about Śaka 900). But no later writers accepted it nor did they attempt to find it for themselves.

---

* Asiatic Researches, Vol. IV.

** Transaltion of the *Sūryasiddhānta* by Burgess, p. 57.

CHAPTER II

PAÑCĀṄGA

(*Almanac*)

The calculation of the five elements or parts (*aṅgas*) of the Almanac (Pañcāṅga) is usually given in the Spaṣṭādhikāra (the chapter on true Places); and hence, the question of the almanac is being taken up in this very chapter. Such matters as the Śaka era, the beginning of the year, the samvatsara (year), the "pūrṇimānta" and "amānta" systems etc. are but integral parts of the almanac; after considering these, therefore, the consideration of the five elements of the almanac, the defferent kinds of almanac etc., will be taken up.

Astronomical calculations require some moment of time to start with in order to predict future planetary positions. In accordance with this convention, the siddhānta works assume the commencing moment of Mahāyuga or that of some other Yuga and especially that of the Kaliyuga as the starting moment for calculation; and the Karana works assume some particular year of the Śaka era as the commencing year. A Karana works two however, can be found to have adopted Vikram Samvat along with the Śaka era. Thus the Karaṇa work *Rāmavinod* has adopted Akbar year along with the Śaka year, and the *Phatteśāha Prakāśa* has adopted the Phatteśāha year coupled with the Śaka year. The *Vārṣiktantra* (page 167), which is really a Karaṇa work has adopted the commencement of the Kaliyuga for the epoch for calculation, and the author has accordingly classed the work as 'tantra'. Even than it has brought in some association with the Śaka era.

A study of different eras

Our almanacs, in their opening pages which are usually devoted to the study of the "samvatsaraphala" (forecast of the year), refer to six founders of eras for the Kaliyuga, like *Yudhiṣthira*, *Vikrama*, *Sālivāhana* and others. Of these, Yudhiṣṭhira and the other to lived in the past and the remaining three are yet to be born. The word Śaka, in fact, denotes a certain tribe of people. Bhaṭotpala and others have stated that the era was introduced under the name of Śaka, since the time when Vikrama defeated the Śaka kings. But this does not appear to be reasonable. The *Śaka* kings themselves may have started the reckoning of the era in their own name. The word Śaka originally denoted a particular tribe, but in compound words like Yudhiṣṭhira Śaka, Vikrama Śaka etc., it signifies time, generally known as 'Era' in English and as 'San' in Arabic. The word 'Kāla' (time) is found to have been used in the sense of era in ancient copper plates. For instance, Śakanṛpa Kāla, Vikrama Kāla, Gupta Kāla (meaning—the era started in the name of Gupta Kings) are some examples of the usage of the word Hence, the word Kāla has been used in the sense of era in the discussion which follows.

Expired year and current year

A number of eras like Vikrama era and Śaka era had been and still continue

Before doing so, however, let some idea be gived about two types of the year : the expired and the current. In the account of Brahmagupta (page 90) the date of compilation of the *Uttara Purana* has been stated to be Śaka 820. But the positions of planets, purporting to be true for the year 820, are found to agree with those for what would be Śaka 819, according to the present mode of reckoning. Hence, one begins to doubt whether the real date of compilation of the Purāṇa was Śaka 819 or 820. The Śaka year which is mentioned as "Śaka 1818" by the almanac-makers of this province and of most of the Provinces in our country is found to have been counted as Śaka 1819 in the Tamil and Telegu almanacs and in some of the Kannad ones printed in Mysore. The reason for this difference appears to be this : The positions of planets given in Siddhānta works are true for the initial moment of the first year of the Kaliyuga. Supposing the positions of planets in the beginning of the 11th year of the Kaliyuga are required, they must be found by adding to the original positions the motion of planets for 10 years, since 10 years would have been elapsed from the beginning of the Kaliyuga to the desired moment. In such calculations the number 10 has to be taken instead of 11. The two dates of compilation of the above Purāṇa, viz. 819 and 820 may possibly be accounted for in some such way. In other words 820 is the current year and 819 the expired year in this case. Similar examples are found in copper plate and other inscriptions. It has been pointed out above that the Śaka year which is numbered 1818 in these parts is counted as 1819 in some almanacs of the Madras Presidency : But there is doubt if the people of that region are really aware of the difference between the expired and current years and if it is taken into account at all for practical purposes. Now-a-days the Tamil almanacs compiled by *Anna Ayyangar* of *Tanjore* District, are in general use in Tamil country of the *Madras* Presidency. The author has procured a number of such almanace for the last several years. Among these, the almanac for the last Sarvajit samvatsara mentions the corresponding Śaka year to be 1809, while the almanac for the very next year, known as Sarvadhārī, compiled by the same author gives 1811 as the Śaka year. These year were counted as 1809 and 1810 in other provinces. It seems that the almanac-makers themselves do not clearly understand the distinction between the expired year and current year ; how can we then expect others to understand it ? On enquiries made of the well-known *Natesh Sastri* of *Madras* and the eminent scholars *Sundareshwar* Shrotni and *Vyankateshwar* Dikshit, from Tiruvadi in *Tanjhore* District, the author has learnt that the year described as "current" above is not at all in vogue in those parts at present. Hence, there is reason to believe that the distinction between the expired and current years must be merely imaginary and that it arose when two different numbers might have been applied by someone to the same year by mistake. If any such distinction exists at all' it can possibly be true only with respect to the Kali era and Śaka era which are in use in works on astronomy ; and of these two, the distinction can be applied with greater clarity to Kali era. The Vikrama and other eras are not in use in astronomical works and no such distinction can be found in their case. However, examples are found in which two different numbers are applied to the same year of the Vikrama era ; but it must be the result of an error. In short, on full consideration. the author is led to believe that, as a matter of fact, there is no such distinction as expired and current year. All years are only current years. For example, the present year (when the author is writing this chapter) named Durmukh (Śaka 1818) is actually 'current'. Later on, in the study of different eras, figures denoting corresponding years have been given

—and compared, and in so doing the system used for reckoning the year number is the same as the one prevalent in most parts of India. In some places the terms 'current' and 'expired' have been used; but they have been used for differentiation in the case of only those years, to which two different numbers are likely to be applied. Let us now consider the different eras.

The KALI Era

The Kali era is used for calculating time in astronomical works and in alamancs. Its years are both **Caitrādi* (luni-solar, beginning from Caitra) and Meṣādi (Solar, beginning from Aries Ingress). The almanacs mention sometimes the current year of this era, sometimes the expired year and sometimes both. It is not met with very often in epigraphical records. This era is not at all used for civil purposes at present. Some almanacs in the Madras Presidency, however, state the year only according to Kali era. The year (expired) according to Kali era is obtained by adding 3179 to the Śaka year.

The SAPTARṢI Era

This era is at present in use in *Kashmir* and the neighbourhood. It seems that it was in use in Kashmir, *Multan* and some other parts at the time of *Albiruṇī* (Śaka 952). The *Rāja-Taraṅgiṇī* has described all historical events only in terms of the years of this era. The era is sometimes known as the "Laukika Kāla" (civil time) or the Śāstra Kāla, (scientific time). This system of measuring time originated in the supposition that the Saptarṣi stars (the Great Bear) have motion, that they take 100 years to pass through one nakṣatra and that they revolve through the zodiac once in 2700 years; thus a cycle of 2700 years has been adopted for reckoning time. But in practice the century figure is usually left out. When 100 years are completed, the counting begins afresh as the first year, second, and so on. According to the astronomers in Kashmir, the Saptarṣi era began from the first lunar day of the bright half of Caitra, in the current Kali year 27. In order therefore, to find the corresponding year of the Śaka era, one has simply to add 46 to the Saptarṣi year, neglecting the centuries; and similarly if 24-25 added one gets the year according to Christian era. The "Saptarṣi" years are Caitrādi. *Dr.* ***Kielhorn* finds that the years in this system are 'current' and the months 'pūrṇimānta' (full moon ending***).

The VIKRAMA Era

This era is at present in use in Gujerat and the whole of northern India except Bengal. The people of these parts have migrated to other provinces but they have carried the use of the era with them. The year of this era is Caitrādi in Northern India. (In other words, the Samvat begins from Caitra). The months are *pūrṇimānta*. But in *Gujerat* the year is Kārtikādi and the months are amānta. In some parts of *Kathiawaḍ* and *Gujerat* the Samvat year is Āṣāḍhādi and the months are amānta. *Prof.******Kielhorn* has examined

**Caitrādi* means "beginning from Caitra"; *Kārtikādi*,, "beginning from Kārtika"; *Meṣādi*, "beginning from Sun's entry into sidereal Aries". (R.V.V.)

** Indian Antiquary, XX, page 149 ff XX.

*** The amānta and pūrṇimānta systems are discussed later on.

**** Indian Antiquary, XX, p. 398 ff.